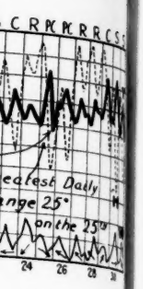

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Heating and Ventilating

Volume 28 NOVEMBER, 1931 Number 11

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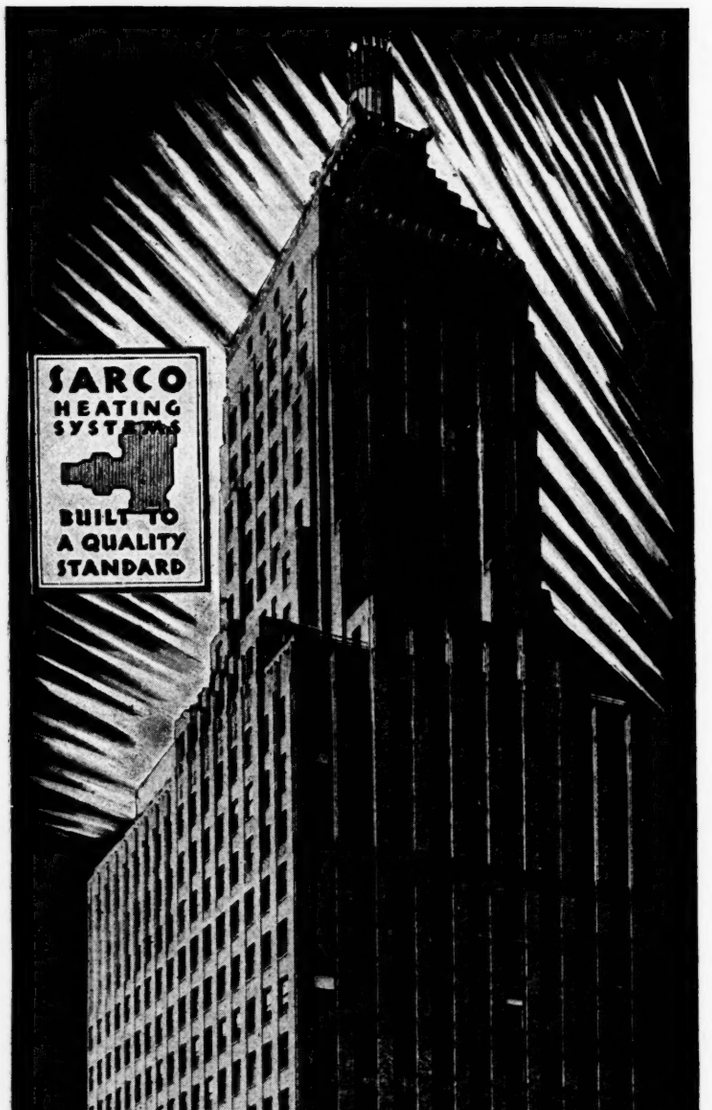

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EDITORIALS

Air Conditioning and the Independent Engineer

IT has been said repeatedly that the day of the independently practicing engineer is past; that the function which he has held will soon be transferred to engineering staffs employed by corporate interests. In many fields of engineering practice such a tendency is marked. It is but mildly true of independent engineers who depend upon heating and ventilating for either all or a goodly portion of their practice. In this field the independent practitioner still wields considerable of his traditional influence and prestige.

In comparatively recent years air conditioning methods have come to play an increasingly prominent part. Many of the details essential to successful application of these methods are not in the possession of independently practicing engineers. The result is that these engineers often have been compelled tacitly to consent to seeing their function in the design of such installations pass into the hands of others.

So far as can be learned no active and effective steps have been taken by independent engineers either individually or collectively to protect their interests in this vitally important matter. It is astonishing that they have no effective means of making their influence felt. Can it be that as a group they do not realize the seriousness of this threat? Or is it merely that they lack the medium of an effective organization to champion their interests?

It is difficult to see how their interests can be protected until some way is found to put them in full possession of all the necessary details. One way would be for them to organize an agency which would have for one of its principal objectives the searching out of the missing items, making them available to all. Would it not be truly unfortunate if the widespread use of air conditioning, which requires so much engineering, should prove to be the means of bringing about the elimination of the independent engineer?

•

Gas Heating Goes Ahead

THE recent convention of the American Gas Association with its attendant reports and summaries serves to call attention again to the steady progress being made by the gas companies in adding to their space heating load. Even during a period of depression the use of manufactured gas for space heating was nearly 28% greater during 1930 than during 1929. Not only is this true, but the use of natural gas is also increasing rapidly.

So far much of the gas has been used for residence and other small building heating. Use of the gas has been based on its convenience and automatic features. Just what effect any reduction of rates due to the advent of natural gas may have on the size of buildings which will use it, is problematical. Present indications are that the use of natural gas for space heating outside of the territories adjacent to the sources will be confined to buildings where convenience is at a premium. Even with such limitations the potential load is enormous. Everyone interested in heating and ventilating must recognize that not only is gas here to stay but that its use is very likely to prove increasingly popular.

Each year the house-heating committee of the association brings out a report filled with valuable information. This year is no exception, and among the interesting points is the following statement: "Present conditions indicate that the type of automatic heating service which is to become the accepted standard for the American home will be the one that is most aggressively merchandized in the immediate future." The committee realizes that gas for house-heating has now reached the stage of a merchandizing matter with most of the technical problems solved. Interest in technique now shifts to problems of cooling and to refinements in heating applications. Much of the steady growth in the use of gas during the past few years has been due to the careful study given to technique, and there is every indication that the problems of cooling will be approached in the same fashion.

•

An Air Conditioning Scale

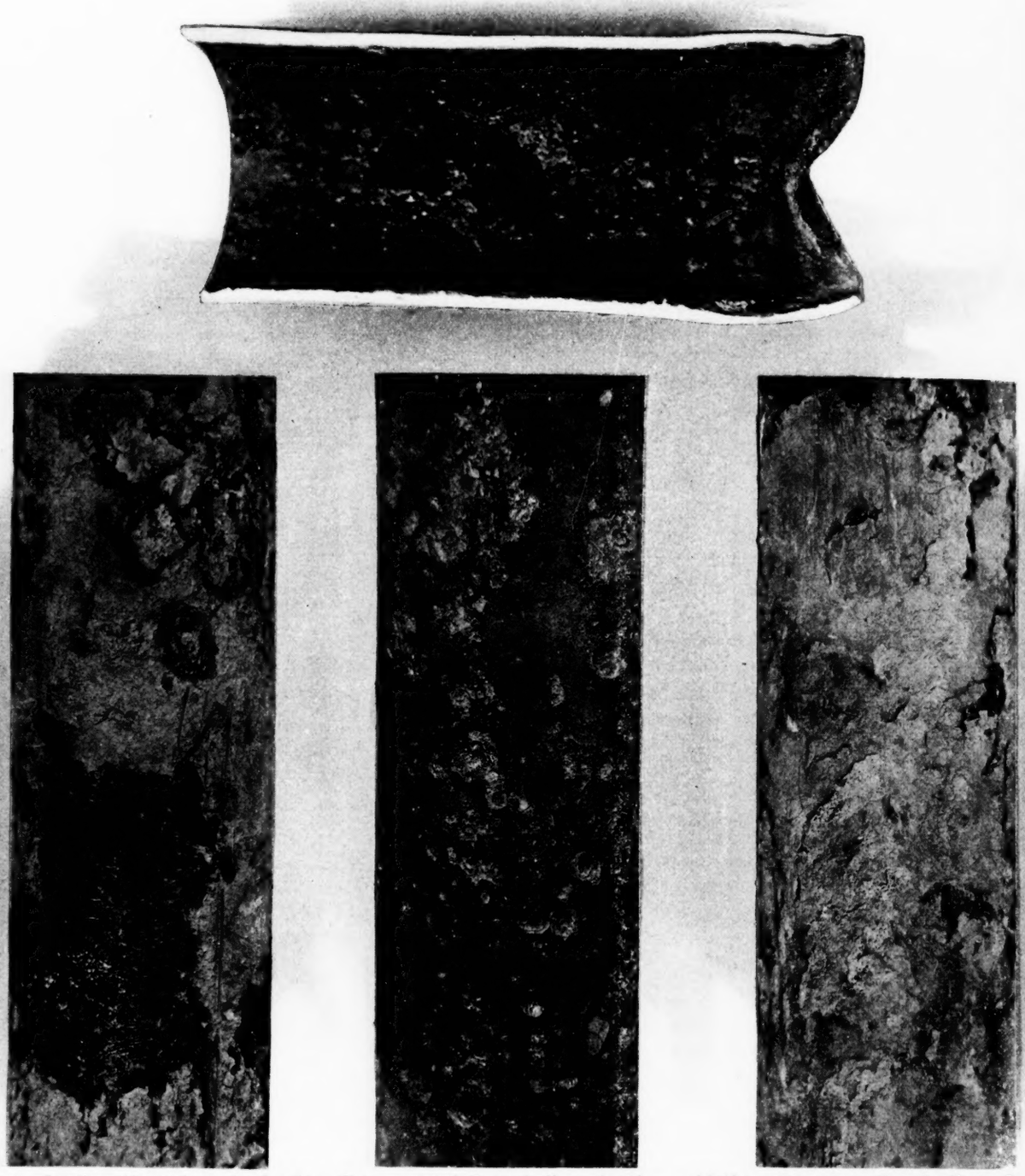
LAST month in this column we referred to the desirability of attempting to build up a systematic series of descriptive words which could be used to qualify the term "air conditioning" in order to free it from some of the evils which are likely to result from its indiscriminate use. This month we are pleased to print a suggestion along this line as received from one of our readers. He proposes the use of a scale which will take into account the number of factors provided for. We feel that while the suggestion made is not ideal, it at least contains the essential germ of a very good idea. The sooner the whole background of air conditioning can be stripped of its mystery, the details brought out into the open, and each installation made for what it really is, the better for all concerned.

Let us have more open discussion, not only on this particular point but on others. In the long run such discussions can result only in good.

Causes and Prevention of Corrosion in Heating Boilers

By G. W. NIGH†

Designers, operators, and contractors will all be interested in this simple but clear and effective statement of the causes and prevention of boiler corrosion. The chemistry of water treatment is not discussed, but the chemistry of the more common causes of corrosion is explained without going into full technical details. Methods of caring for boilers both in and out of use are given.



(Top)—Section through end of tube after removal from boiler, showing oxidation progress and reduction of wa thickness. (Left)—Section of tube covered with heavy scale. A portion is descaled to show metal underneath, u corroded because protected by scale. (Center)—Note craters produced by localized electrolytic action in this sectio of tube with no protecting scale. (Right)—Section of tube coated with very heavy scale of the type which cause burned metal and failure.

IN this article discussion is confined to steel boilers such as are used so generally for heating and smaller power purposes. It must not be assumed that the practices and recommendations made are the only ones possible, for as our technical knowledge enlarges newer and better methods are being developed.

The word *corrosion* as applied to steel boilers is the common term for chemical action on the plates as a result of which the metal is changed to an iron compound. This corrosion can be divided easily into two classifications: first, corrosion from the water side of the steel brought about by the action of the hot water inside the boiler; second, corrosion which takes place on the gas side of the steel on the surfaces exposed to the hot gases.

Corrosion on the water side will be discussed first because this is the more common. Also, it is the most difficult of boiler troubles to overcome.

In order to make clear the basis of the chemical action, let us digress into the field of pure chemistry.

Water, the common chemical being boiled or evaporated to form steam, is composed of two elements—hydrogen and oxygen. Two atoms of hydrogen unite with one of oxygen, hence the chemical formula H_2O. Both these elements are gases at ordinary temperatures in their free state. When combined, they form one of nature's best solvents, so that, in nature, water is never free of dissolved matter. But water alone—pure—will dissolve only a very minute quantity of iron from the surface of a steel plate. Hence, the solubility of iron in water is not a source of trouble in boilers.

The theory, explaining the corrosion or dissolving of iron from steel surfaces, most generally recognized today is the electro-chemical. Essentially this theory states that when two metals having a difference in electric potential are immersed in an acid bath a galvanic action takes place. This is illustrated by the now obsolete copper-zinc wet batteries.

A steel plate has a crystalline structure made of crystals of iron or ferrite, of iron carbide—where iron and carbon have united—and of various intermediate stages between the ferrite and iron carbide. There is an electric potential difference between ferrite crystals and the other crystals. Thus, there is provided at once a condition for local galvanic action between portions of the surface of a steel plate. If the steel is immersed in water, this galvanic action will start. The cathodic or negative portions will be attacked, oxygen atoms from the water uniting with ferrite atoms to form an oxide, or rust. The hydrogen freed by these oxygen atoms collects on the oxidized surface as minute bubbles, and, when a coating is formed, protects the iron from further galvanic action. The local cell is then *polarized*.

In the old wet cell, continuous duty required some method of removing the hydrogen bubbles, or depolarizing the cathode. Likewise, on the steel plate continued action is possible only if the local cathodes are depolarized. Free oxygen in the water is very active as a depolarizer, uniting with hydrogen bubbles, thus allowing galvanic action to continue. In a boiler, the circulation of water tends to wash away the hydrogen bubbles, allowing corrosion to continue. However, the mechanical action of water is not very effective, and hence corrosion is not rapid in the absence of free oxygen unless an active acid is present.

This action of oxygen is elaborated upon because, at first thought, it is not evident how steel can be dissolved in such a weak corrosive liquid as water. All acids will produce a corrosive action on steel, and water is really an oxygen acid although it is rated as neutral between an acid and an alkali.

The presence of carbon dioxide in water forms a carbonic acid. While this is a weak acid, its action is like that of free oxygen in water.

It is possible to have a pronounced acid action when certain neutral salts are dissolved in boiler water. For instance, magnesium chloride in solution when heated to the boiling point breaks down and releases hydrochloric acid, leaving magnesium oxide. The hydrochloric acid attacks the steel, forming first iron chloride, then iron oxide, thus releasing the hydrochloric acid to go through the cycle again. It is easy to see that a small amount of magnesium chloride or free hydrochloric acid can do considerable damage to boiler plate.

As any free acid will corrode a steel plate, it is obvious that the boiler water must always be kept alkaline. The degree of alkalinity is indicated by a factor the chemists have evolved. The relative alkalinity or acidity of a solution is indicated by its pH value or potential hydrogen factor. Pure water is considered neutral and is the basis for this factor. Pure water dissociates slightly in its natural state into hydrogen and oxygen ions. The degree of dissociation is very small, $1/10^{-7}$ for each. Then the pH value for water equals minus the logarithm of H for dissociated ions, and equals 7 for pure water. Hence, an acid solution has a pH value of less than 7, and an alkaline solution has a pH value of greater than 7. For example, full strength hydrochloric acid has a pH value of about 1, while saturated sodium hydroxide has a pH value of approximately 13. Keeping these figures in mind helps one to sense the water condition when its pH value is given.

Turning now to the corrosion on the gas side of the steel surface, the action is not so complex. During service, when the gases and steel surfaces are hot, there is little or no corrosion because there is no water to form the basis for a chemical action. But during the period when the boiler is out of service, as in the summer months, the boiler is cooled down to atmospheric temperature. When the boiler room temperature changes so that it is higher than that of the boiler, the boiler surfaces may "sweat." That is to say, water will precipitate on these cool metal surfaces from the air. As this water will have free oxygen in it, the action described above can take place if sufficient water is collected. Moisture on surfaces covered with a deposit of soot will usually form a sulphuric acid with the sulphur compounds deposited from the coal. Since this is a very active acid, when it is present in any quantity the corrosive action is rapid. In fact, if tubes are badly sooted up, it is possible to ruin a set entirely during one summer out of service.

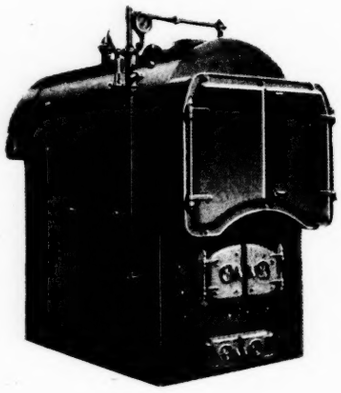
After discussing the corrosive actions on boiler

[†]Chief Engineer, Coatesville Boiler Works

plates, the next phase to consider is the methods and means of detecting when a corrosive condition exists. This is necessary before remedial steps are taken.

If chemical analyses of the water are made periodically, much can be learned about the boiler condition. This will indicate whether the water is corrosive or scale-forming, and also if the concentration is enough to cause priming.

Another method which should always be used to supplement chemical analysis is that of direct inspection. At regular periods the boiler should be drained, inspected, and then washed out. If the metal is clean, it means that conditions are ideal for corrosion to take place. A heavy scale is bad and must be corrected at once. A thick, rotten scale can be washed off or removed by treatment, but a hard thick scale can quickly ruin a boiler. The ideal condition exists when there is a very light, soft scale of paper thickness. This means that the metal surface is protected, but heat transmission is not retarded.



Possible corrosion of the gas side of surfaces is not so easy to detect. The best place to look is just inside the ends of the tubes. Here the metal has been stretched by rolling; the mill scale has been broken, and if acid action is present it will be here. It will usually be found inside tubes at the bottom.

Bad boiler action caused by priming sometimes can be detected to advantage by examining the water or condensate from the traps draining the main instead of examining the water in the boiler itself. If this condensed water tests strongly alkaline, it indicates that the boiler is carrying over water by foaming or priming. The condensate from dry steam is pure neutral water.

When periodic inspections indicate a condition other than ideal, steps must be taken to apply remedies. First and most important of all cautions to be given is—do not use any so-called boiler compound until a water analysis shows that the particular compound is suited to that particular water. A cure-all boiler compound never has been and probably never will be found. Boiler waters vary widely. Periodic washings and inspections should be made just often enough to know the conditions in the boiler. When the boiler is new, the addition of lime to the feed water at the rate of one pound per thousand gallons is often recommended on the assumption that it will slowly form a thin coating of lime on the heating surfaces. This coating is alkaline and makes an ideal protective covering. This method is also used to advantage when a boiler has just been retubed.

Turning now to the most common corrosive agent, viz., free oxygen, the most difficult problem is encountered. The remedy may be either elimination or protection. To eliminate oxygen from the water is most difficult. In a heating boiler the return water is condensed steam. Such pure water is free of air and will quickly absorb some when it is available. Air leaks into the system at various places, such as through air-vent valves, pump packings, and shut-off valve packing. There are so many possible places that it is almost impossible to keep some air from getting into the water. It is safe to assume there is always some oxygen in the return water.

This oxygen can be eliminated or removed just before the water goes to the boiler. Two methods are used. One of these is called deaeration. By contact with live steam, water in a spray is flashed to a vapor, thus driving off the dissolved gases. This method is easily applicable where a pressure is always available at the boiler, but cannot be used on low pressure jobs where there is a negative pressure at the boiler some of the time. Another method is called deactivation. In this the oxygen uses itself up by acting upon other metal such as steel scrap which is placed in a tank through which the water is passed on its way to the boiler.

On pressure jobs, deaeration is widely used as representing best practice. Where that is not possible, the deactivation method is left and can be used on low pressure or vacuum jobs.

If neither of the methods is used, the remedy of protection is still available. The action of the oxygen can be greatly retarded by keeping the water alkaline, as with an hydroxide. The action of the hydroxide is to form a film of ferrous hydroxide on the steel. This film is protective against oxidation and against further action by the alkalinity of the water. Other coatings on the tube surfaces are effective. The film of lime noted above is alkaline in reaction and protects the surfaces from action by oxygen or by an acid. Having a protective coating on the surfaces, if the concentration of dissolved solids in the water does not increase due to raw feed water, there is very little to do regarding the water. In fact, it is often better to do nothing. But if the soluble content builds up, the priming point will be reached unless some treatment of the water is practiced.

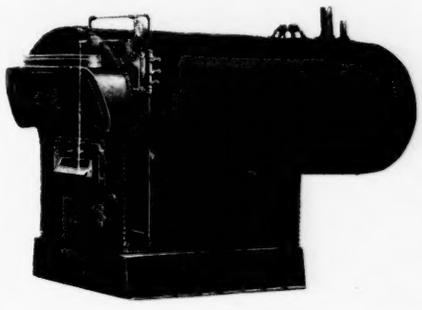
In cases where the soluble content consists largely of salts of sodium or potassium, the best method is to reduce them by sufficient blow-down to keep the concentration below the foaming point. When using the blow-off, boilers, having part of the feed made up of condensate, usually require not more than one gauge in twenty-four hours. The blow-down period should come at an off-load time when the boiler is not working hard, in order that the low rate of water circulation

may allow the undissolved solids to collect at the blow-off outlet.

The presence of sodium hydroxide in large quantities in boiler water produces a condition favorable for "caustic embrittlement" of the boiler plate. This is not a corrosion effect in that metal is not taken away. Instead the bond between the crystals in the steel is weakened so that failure can occur with no elongation in the metal which is very ductile when new. Caustic embrittlement is more to be expected when a boiler is forced to high rating. The action is concentrated at joints, failure often occurring at the ligaments between rivet holes.

The remedy for this chemical action is chemical. It is to keep the percentage of alkaline sulphate twice that of the hydroxide. The sulphate seems to protect the steel crystals from caustic action.

A high concentration of dissolved solids will precipitate the least soluble ones. Some will form scale which is not corrosive in action but still harmful. Calcium sulphate is a common impurity which is hard scale forming. Proper treatment of the water under these conditions is necessary to prevent having a coating of hard scale. As such hard scale is not corrosive, a discussion of the matter does not come within the scope of this article.



Discussion of the corrosion of steel surfaces exposed to the hot flue gases is not so involved. As this corrosion is slight when a boiler is in service, this phase of the subject will not be developed. The corrosion which takes place when the boiler is out of service is of important magnitude, but can be reduced practically to zero by proper maintenance and preparation of the heating surfaces.

When a boiler is to be taken out of service for a period of time, such as during the summer, it should be drained of all water, hand-holes and manholes should be opened, and the boiler should be thoroughly washed inside. Openings left uncovered will provide air circulation to dry the wet, freshly washed surfaces. Next the gas surfaces should be thoroughly cleaned of all soot and dry ash. This applies especially to the tubes and the tube ends. After being thoroughly cleaned, they should be well slushed out with a heavy non-vaporizing oil. If the out-of-service period is to be long, say years, the boiler shell or firebox should be painted with a moisture-proof paint, which can also be used inside the tubes.

In the summer time, when the temperature of the boiler room changes, the boiler surfaces will tend to sweat or collect moisture from the air. This moisture, as noted before, forms a corrosive acid with the sulphur compounds in the soot. Hence, the preventive action is to keep the moisture from forming the acid, or if the acid is formed, to keep it away from the steel. Making the surface waterproof with a heavy oil or a paint is the only really effective way, unless all the sooty deposit is removed. Even then the surface should be protected because the collected moisture contains oxygen. When cleaned and painted with oil or paint, the setting should be closed tight to stop all air circulation. At the same time, all openings into the boiler shell should be closed air tight. It is advisable to put a tray of unslaked lime on top of the tubes in places where the boiler room air is very damp at the time of closing the boiler. To check out-of-service corrosion, keep the steel surfaces dry. This can be adequately attended to by the boiler operator.

A few comparative notes follow: A quick steaming boiler has rapid circulation and will corrode more rapidly than one having a more sluggish circulation. The latter, however, will be more prone to allow heavy scale to form on the heating surfaces, and hence, in time, to burn. A boiler in a damp or wet boiler room will be more difficult to maintain out-of-service without corrosion than will a boiler in a dry boiler room.

One of the things most dangerous to a boiler is the cure-all boiler compound. One instance is recalled where an enthusiastic salesman demonstrated to a hotel manager's satisfaction that his compound would not injure a boiler. He added some to a glass of water and drank it to show that it would not corrode the inside of a boiler. Nevertheless, in two months after starting the use of this compound the hotel's new boiler had to be retubed.

Boiler water for heating plants should, where it can be afforded, be treated under the guidance of a chemist. Small plants can be as careful as are large power stations and their operators will be rewarded with long life from the tubes. Plants which cannot afford a chemist's service often can get the city water analysis from the city. Its pH value will indicate whether it is acid or alkaline and to what extent. If acid, the operator must treat it to secure alkalinity, and he can check this by a simple test such as using litmus paper. A lime protecting coating and frequent washings will handle most waters. The use of either method is extremely simple.

Improved design of steel boilers has increased their output to such an extent that now their steaming rates are higher than ever before. This means higher temperatures in the tubes and more rapid evaporation of the water.

To get long life from the boiler requires better care by a more intelligent operator than in years gone by. It is, therefore, up to the operator to improve his knowledge of boiler operation as much as the boiler

manu urer has improved the boilers.

The chemical actions here discussed are by no means always present in steel boilers. Where a good grade of boiler water is used, or where but little make-up water is required, steel boilers operate for years with but slight attention. With proper attention, steel boilers will last for many years, and thousands have lasted for years with no attention.

Utility Steam Plants for Combination Service

FOR some time utility steam plants have been operating to serve as a source of electrical energy, steam, hot water, and other service needs of industrial plants, while any surplus of electrical energy generated is absorbed by the distribution system of electrical utility companies, and any deficiency in electrical energy is supplied from this system. Such plants are usually located at or near the industrial plant and are operated under agreements between the utility and the industrial company concerned. The report of the research committee of the National District Heating Association at the 1931 meeting at Boston contained a statement of the general reasoning favoring the use of such plants, and a description of the principal features of some of the plants now in existence:

"Since the development work on high pressure boilers and high exhaust pressure turbines has progressed to a point where both are as reliable as the low pressure units, it is possible for the industries to build their own power plants and generate steam and electricity at a figure which compares favorably with the cost of such service from a public utility. But the industry cannot always take full advantage of all possible economies because their steam requirements and power demands are seldom such that a balance can always be maintained, thus permitting the plant to operate under the most favorable conditions.

"When the industry and the utility are both interested in the requirements of the industry, it is possible to design and operate a plant which will supply the industry its requirements at a cost which will be less than the industry could furnish it from its own plant.

"This combination plant has been called the 'dual service plant' by some utility executives, but since many industries require other services such as compressed air, refrigeration, and manufactured air, in addition to heat and power, this type of plant might better be called a 'Combination Service Utility Plant.'

Lower Costs Made Possible

"Lower costs are possible in these combination plants because in most industries the cost of power is only about 5% or 10% of the total production cost, and therefore the power plant does not receive the type of supervision as that in a utility plant where steam and power generation represents 100% of the plant costs.

"The industry is less able to take advantage of new developments because their demands for increased capacity are not as large or as frequent as in the utility plant and because their requirements may be such that it would be impossible to adapt these new developments to existing conditions. As an example a more efficient turbine would increase the power generated with the same steam consumption. If the industry could not use the additional power they would not be justified in installing the new machine, assuming their requirements for steam remained constant.

"In plants where steam is used in process work, it is possible to generate electricity in bleeder turbines at B.t.u. cost which is only about one-fourth that of a condensing plant.

"The combination utility service plant is able to dispose of all electrical generation or may be operated at its most favorable load and receive the remaining power requirements from the electrical system of the utility.

"Although many utility executives do not agree that plants such as these should receive any capacity credit due to their size in comparison to the units in the main generating stations, nevertheless, it places this capacity at the load center, eliminating transmission investments and losses. This capacity can be installed for from one-fourth to one-half of that in the main generating stations, due to the elimination of condensers, vacuum pumps, cooling water canals, and transmission systems.

Long Term Agreements Necessary

"Such combinations must necessarily be based on rather long agreements because of the finances involved but with all parties sharing in the additional economies such arrangements are desirable."

Among the plants of this kind mentioned in the report are:

1. Southeastern Production Company. A plant located at a paper mill of the International Paper Company, Mobile, Ala., supplying power and process steam to the paper mill.

2. Louisiana Steam Products Plant. Located near Baton Rouge, La. Intended to supply process steam and power to the Standard Oil Company of Louisiana, and power to an inter-connected utility system.

3. Point Breeze Plant. Located near Baltimore, supplying a Western Electric plant with process and heating steam. Plant erected by the manufacturing company and operated by the Baltimore Consolidated.

4. Cedar Rapids. Furnishes steam and power to a mill of the Quaker Oats Company and steam to a district heating project.

5. Deepwater Plant. Located in New Jersey on the Delaware River near Pennsgrove. Operated under a tri-party agreement between two utilities and the Dupont Company. This plant contains many novel features, some of which are outlined rather fully in the report.

Vital Questions in Air Conditioning‡

By M. G. HARBULA†

Does a blanket guarantee of air conditioning capacity, including temperatures and humidities to be maintained, protect the engineer's client or not? Shall plans and specifications for air conditioning be prepared by the consulting engineer or by the manufacturers of equipment?

Is first cost alone of primary importance in air conditioning—or does operating cost enter the picture?

What constitutes a disagreeable draft?

Shall the differential between the entering air temperature and the maintained temperature be large or small?

Is the 30 cu. ft. per min. per person rule acceptable for air conditioning as well as for ventilation?

The author frankly discusses these and other pertinent questions which are being raised about the present practices surrounding air conditioning.

NOW that air conditioning for comfort is growing so rapidly, engineers are becoming increasingly interested in finding out the whys and wherefores connected with some of the practices which have gradually grown up in connection with it. Thoughtful attention to the elements of the subject, close examination of existing practices, and free discussion are needed if real progress is to be made. The writer is convinced that the time has come when discussion of some of these points is highly desirable.

First of all there are questions regarding the relative desirability of methods of assuring the continued popularity and growth of air conditioning.

In the past, a method of procedure often used in large installations has been for an engineer who represents the owner's interests to depend very largely upon the advice and cooperation of manufacturers and contractors. This was often carried to the point of depending upon them actually to prepare the plans and specifications. As a result, such manufacturers and contractors fixed the temperatures and humidities to be maintained, amounts of air to be circulated, amounts of outside air to be drawn into the building. They determined the capacity and number of refrigerating machines, settled upon the refrigerant to be used, decided upon details of condensers and evaporators and pumps, determined water circulating sources and methods of handling, decided upon the means to be used in introducing the air into the conditioned spaces and of exhausting it therefrom, and passed upon questions of whether or not automatic control devices should be used. In short, they either entirely designed the installation, and often drew up the specifications, or else the consulting engineer depended upon them to such an extent that they virtually did so.

Engineers have apparently felt justified in following such a procedure, either because they felt that they themselves lacked the necessary information and experience, or that they could depend upon protecting their client's interests through the guarantee given by the manufacturer or contractor, or because of the quality and skill of the engineering staffs so often employed by manufacturers and contractors.

Undoubtedly the staffs employed by many of the manufacturers and contractors are both skilled and thoroughly competent. Also, no doubt, many fine installations have resulted from following the procedure outlined. In fact, such procedure has some advantages where competitive bidding is not used in the awarding of contracts. On the other hand, it makes the independent engineer practically valueless to his client and the manufacturer is confronted with a natural temptation to load the plans.

Where the owner is interested in securing competitive bids (in other words, where both first and operating costs are matters of importance), the use of such a procedure is open to question, both as to value to the owner and as to fairness to the several competitive bidders.

To make this clear let us consider an example. Suppose that manufacturer A has been asked to prepare the plans for a certain job and has done so. In this he merely outlines the general nature of the apparatus to be included and states the conditions of temperature and humidity which he proposes to maintain. In some instances motor horsepowers are specified in order to facilitate the determination of wire sizes and accessories. In order to offer the owner protection he undertakes to guarantee the job in the following terms[1]:

> "This equipment, when installed and operated in accordance with our instructions, is guaranteed to be of sufficient capacity to perform the following:
> "1. To cool the spaces to which it is connected, in summer, to an average temperature not exceeding 80° F. when the outside dry bulb temperature is 95° F.

[1] This guarantee is taken from the specifications used in connection with a bank building. It is chosen not as being any better or worse than any other, but as being typical, and as illustrating the point under discussion.

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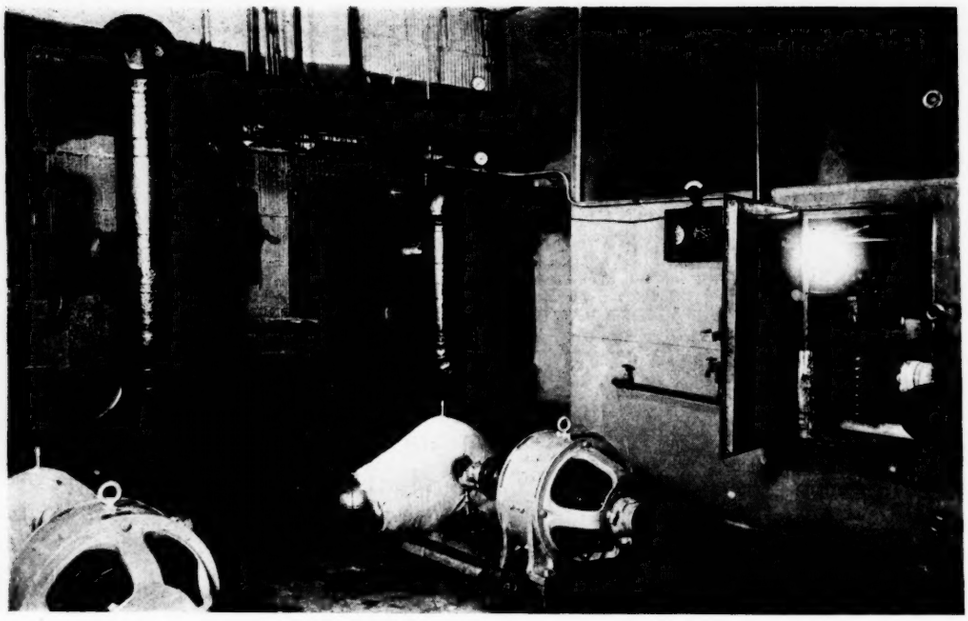
†Consulting air conditioning engineer, Glen Ellyn, Ill.



Cold water pumps, water cooling equipment and air conditioning machines in Keith's Palace Theater, Cleveland. The air conditioning was designed by the author.

"2. To maintain a relative humidity not exceeding 55% when the maximum outside entering wet bulb temperature is 75° F.

"3. To heat the spaces to which it is connected to a temperature of 70° F. in zero weather when heaters are supplied with sufficient steam at 5 lb. pressure.

"These guarantees are made with the understanding that the building will be made reasonably tight to prevent entrance of outside air, and that all the doors, windows and other openings, except the public entrances, will be kept closed. The guarantees contemplate further that no more than 275 people will be in the room at one time."

The engineer incorporates the plans and the guarantee into his specifications and is ready to recommend that the owner let the contract.

Now let us suppose that contractors and manufacturers B and C are asked to bid on the same basis as A, with the contract to be awarded to the low bidder. They immediately note that the items of equipment are not exactly specified as to capacity or performance and that the guarantee calls for "sufficient capacity" for the installation as a whole, subject to the several restrictions mentioned.

Let us look into this matter of sufficient capacity of the plant as a whole. Does such a blanket guarantee of the capacity of the installation really protect the owner—the engineer's client—or does it not? This is one of the vital questions which should be frankly faced and thoroughly discussed.

Every air conditioning plant has a definite duty to perform and the provision of sufficient capacity is certainly essential. The capacity of the whole plant is, however, a sort of overall combination of the capacities of the individual items which go to make it up. Some of these individual items of equipment have capacities which are flexible. For example, it is possible to cause a small fan to deliver as much capacity as a large one by speeding it up, with a resulting high power requirement and naturally objectionable noise which is not mentioned in the guarantees; a small condenser may be made to deliver capacity by flowing excessive quantities of water through it; a relatively small displacement compressor may be made to compress more refrigerant by speeding it up, thereby causing rapid wear. It is thus possible to deliver "sufficient capacity" with the plant as a whole even though each item of equipment is skimped in size, but in each case it is being done by using the apparatus inefficiently. In the long run, therefore, does not the owner pay for this in his unreasonably high operating costs? Is the engineer, therefore, fully protecting his client's interests when he is satisfied with a guarantee of sufficient capacity?

Let us see what happens in our example. Bidders B and C note the wording of the guarantee and the absence of specific requirements. They consequently base their bid on the use of the least possible capacity of apparatus and higher speeds, which will all fill the bill. As a result, the owner may get a low first cost plant but he will pay high operating costs and will always have excessive maintenance and repair bills.

Use of such a procedure in preparing plans also lends itself to another possible evil—that of substitution of materials. It is possible to use a carefully-built and well-braced casing for the air washer made of a heavy gauge metal, or to use a flimsy makeshift of light construction. Either will deliver capacity to meet the terms of the guarantee but the one will have short life, a fact which the owner will learn only after the contract is executed and completed. The same is true of the metal used for ducts and, in general, of all the fabricated materials involved. In competitive bidding under such a guarantee the bidders are practically invited to figure on the use of as light and cheap material as *they* consider suitable, and the one which they naturally consider suitable is the one which will take the bid.

Still another point concerning a guarantee embodying capacity only is that no mention is made of the uniformity or lack of uniformity of the temperatures and humidities to be maintained inside the space. Capacity only is guaranteed. The uniformity of maintained con-

ditions depends almost altogether upon the methods of introduction and exhaust. No mention is made concerning freedom from chilling drafts at the time the plant is delivering the sufficient capacity, or at any other time. Here is a very important point. Should not the owner be assured that the installation will function properly in every detail, as well as possess sufficient capacity?

There is no point in discussing the details of any specific guarantee, for the exact wording of such a statement is a matter to be decided by policy or agreement in any particular case. Enough has been said to call attention to some of the undesirable features of such a plan. There is point, however, in raising the question whether any guarantee can take the place of a carefully drawn and detailed set of specifications and plans which accurately set forth the capacities of each individual piece of equipment and show its position, and tell how it is to be installed.

Is it not true that if the use of air conditioning is to become widespread, the owner is the person who eventually must be satisfied? Is it not also true that, in order to do this, high class installations must be made which will not only be reasonable in first cost but which will also operate economically and with low repair and maintenance costs?

Who is to function as the representative of the owner in this work? Since air conditioning plants involve so much of technical and engineering skill, obviously an engineer is the logical representative. Shall he be an independent consulting engineer, or shall the engineering be left to the staff employed by manufacturers and contractors? The independently practicing engineer is vitally interested in this question. If he fits himself to be able to handle the full and detailed preparation of plans and specifications for such work he stands to increase in number and in importance as air conditioning increases. If, on the other hand, he is content to delegate this work, is he not setting the stage for his own ultimate elimination?

The Question of Air Quantities

Another question which is vital to the progress of air conditioning is that of the amount of air to be handled through the apparatus. It would seem to be almost axiomatic that the quantity most desirable from an operating and economy standpoint is the least quantity necessary to absorb the heat and moisture from the conditioned space in summer, and to give up to the conditioned space the required amount of heat in winter. The amount of air necessary in either case depends upon the allowable change in temperature of the air during the cycle of circulation in the plant. That is to say, the amount necessary depends on the difference between the temperature at which the air is introduced into the conditioned space and the desired temperature to be maintained. It is generally accepted as true that this difference is limited by the production of uneven temperatures or drafts. The existence of these conditions depends on the methods used in introducing the air and in exhausting it. That is the same as stating that, in the last analysis, the quantity of air to be circulated through the system depends on the methods of distribution and exhaust used.

So far as the writer can determine no actual research work conducted by a disinterested agency has ever been undertaken to learn if there is really a relation between the temperature changes and the appearance of disagreeable drafts. No one has demonstrated in unmistakable terms that there is an actual limit beyond which the temperature change cannot be carried. There is evidence to show that the temperature change is a function of the distribution methods used, for some methods do produce disagreeable drafts with but small temperature changes, while others do not. Thus, an underfloor method of distribution requires an entering air temperature but slightly different from that to be maintained; a method using a multitude of small openings with downward discharge directed at the occupied zone may operate successfully at considerably greater differences than an underfloor upward method; horizontal openings may also be designed with large temperature differences and the accompanying small quantities. It has been intimated that the temperature change per foot of vertical height is directly and simply related to the minimum entering air temperature, but direct proof of this is lacking.

The whole question of air quantities to be circulated is, consequently, a matter of the relation between distribution methods and the appearance of disagreeable drafts. Not only is there little information available as to the limitations of the several methods but, moreover, there is no agreed-upon definition as to what does in fact constitute a "disagreeable" draft. When it is recalled that all of this is undoubtedly also dependent on local conditions, such as room dimensions and surroundings, as well as the actual skill of the designer, it can be appreciated how complicated the question becomes. Yet until more information is in the hands of designers the progress of air conditioning is likely to be impeded.

There is some question also as to whether cooling or heating operation fixes the maximum requirement of air quantities to be handled. Generally, however, the introduction of cold air into a space, and its proper distribution to bring about the desired results, is a more difficult problem than is the introduction of air warmer than the desired condition. Consequently, the air quantity is considered as being fixed by the limitations found during summer operation rather than during winter operation. In this case, the temperature change is a rise in temperature as the air passes through the conditioned space. The whole question then is: How much less than the maintained temperature can the temperature of introduction be?

To get a true picture of the present situation let us just note in passing the background behind present ideas as to the air quantities.

In the early days of air cooling installations difficulty was encountered by designers in attempting to find suitable means of distributing the cooled air satisfactorily. Moreover, ventilating ordinances often demanded the circulation of 30 cu. ft. of air per person per minute. This quantity was arrived at by analyses quite different from those encountered in air cooling installations, and

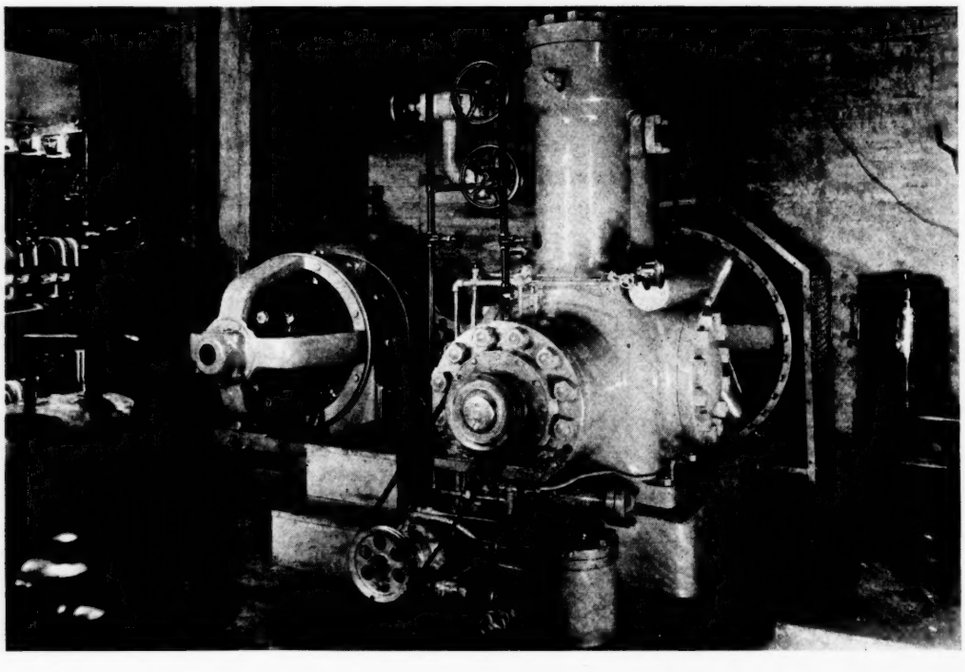
are so well known that there is no point in repeating them here. Suffice it to note that ventilating practice called for the use of large air quantities. Probably this background of ventilating practice affected the early air cooling installations. At any rate, when difficulty was experienced in securing satisfactory distribution the natural tendency was to revert to the idea of circulating large quantities of air with a small temperature rise. Under such conditions the design of air distribution fixtures, outlet locations and other bothersome details could be avoided to a considerable extent. Finally, a practice grew up more or less tacitly of fixing the temperature rise at around 10°. Examination of a great number of plans, specifications and calculations by the writer shows that with this temperature rise the quantity of air to be circulated is usually in the neighborhood of 25 cu. ft. to 30 cu. ft. per person per minute in theater installations and in buildings of like character where density of occupancy is comparatively high.

There always were, however, those who felt that the use of smaller air quantities at greater temperature differences was desirable and such installations have long been in existence. Recently, too, study has been given to distribution design details and the question is raised as to whether or not the use of quantities of air as great as 30 cu. ft. per person per minute, or equivalent quantities based upon amounts of air per square foot of floor space, are any longer either necessary or justifiable. Occupied rooms with ceiling heights as low as 10 ft. are now being successfully cooled with small air quantities delivered into the room as much as 35° below the maintained temperature. A number of modern, de luxe theaters are equipped with cooling plants that are handling as little as 15 cu. ft. of air per occupant per minute and delivering this air at the rear of the auditorium as low as 14 ft. over the heads of patrons and at a temperature 20° lower than the maintained temperature. Probably the most recent case, and one worthy of mention, is in connection with some of the air conditioning work for Radio City, the amusement center being erected in New York, where the writer recommended air inlet temperatures 22° below room temperature. These recommendations are apparently to be incorporated in the designs.

Supplying more air than actually required for absorption of heat and moisture emitted in a cooled space has almost no appreciable effect upon effective temperature. Assume, as an example, that 15 cu. ft. are supplied per person per minute, and this amount is producing a movement of air within the cooled space equivalent to a velocity of 100 ft. per min. By supplying 30 cu. ft. per person, an increase of 100%, the velocity of air would be 200 ft. per min., resulting in a reduction of effective temperature within the comfort zone of barely one degree. To gain the effect, therefore, of this one degree of cooling it is necessary to increase the capacity of fans, motors, ducts and all auxiliary equipment 100% as well as enlarge considerably the amount of space required for all this equipment.

When the tremendous importance and the effect which the quantity of air being handled has on both the first and operating costs of air conditioning plants are considered, is it not time that careful thought be given to the possibilities? Can the accumulating evidence of the possibility of keeping the temperature differentials large and the air quantities small be disregarded? Small air quantities reduce equipment sizes, but the lowering of cost should result in the more rapid acceptance of air conditioning to the great benefit of all concerned.

One additional point in this connection is noteworthy. Should not the efforts of all be directed toward discouraging the passage of new ordinances fixing air quantities at, or in the neighborhood of, 30 cu. ft. per person per minute until both the old and the new evidence found in the success of installations handling smaller quantities can be systematized and organized and until additional information is at hand as to the limits of the temperature changes which are practicable?



Refrigerating compressor in the Keith Palace installation

A Discussion of Reversed Refrigeration

By W. M. BENJAMIN†

AN article[1] describing the reversed refrigerating cycle which appeared in a recent issue of HEATING AND VENTILATING may leave some readers with an erroneous impression of the economy of this process, due to the omission of several practical considerations involved in the development of a workable set of equipment for the cycle. It is the intent of this discussion to point out certain difficulties which stand between the theoretically excellent performance and the actual performance of this heat pump.

As a beginning, the reader will recall that the highest thermal efficiency possible with any heat engine is that of the Carnot cycle which may be expressed as $\frac{T_1-T_2}{T_1}$ where T_1 is the absolute temperature of the heat source and T_2 is the absolute temperature at which heat is rejected. In case the cycle is reversed, as proposed for building heating, the outdoor air becomes a heat source, and the condenser absorbs the rejected heat for distribution within the building. In this case the efficiency, or coefficient of performance, is given by the reciprocal of the Carnot efficiency or $\frac{T_1}{T_1-T_2}$

In the example cited[1], the temperature of the heat source (the outside air) is $T_2 = 460° + 10° = 470°$ F. absolute. The condenser temperature is given as $460° + 70° = T_1$. The theoretical performance coefficient of the cycle is then $\frac{530}{530-470} = 8.83$. In actual practice the theoretical performance cannot be attained due to the need for some difference between the temperatures of the working medium and those of the heat source and of the condenser. Friction losses in the heat exchange apparatus, and mechanical and electrical losses in motors and compressors, contribute further to reduce the actual performance below the theoretical.

In calculating the actual performance of such a cycle, care must be taken to select pressures and temperatures properly. Investigation of temperature conditions for the condenser in the example[2] reveals the fact that the cycle will not work with the values assumed, for reasons stated below.

The heat content of the vapor at the end of compression is 611.8 + 88.0 = 699.8 B.t.u. per lb. (See the temperature-entropy diagram, Fig. 1.) The heat of liquid ammonia at the expansion valve is 120.5 B.t.u. per lb. The heat removed in the condenser is, therefore, 699.8 — 120.5 = 579.3 B.t.u. per lb. The water in coil A is assumed to enter the condenser at 60° and leave at 90°, undergoing a temperature increase of 30°. The amount of cooling water is, consequently, 579.3 ÷ 30 = 19.3 lb. per lb. of ammonia. Now, the heat content of saturated ammonia vapor at 70° (128.8 lb. abs.) is 629.1 B.t.u. per lb. and that of liquid ammonia at 70° is 120.5 B.t.u. per lb. The latent heat of 508.6 B.t.u. is the amount that must be absorbed at 70°. The temperature rise of 19.3 lb. of water in absorbing 508.6 B.t.u. is 26.3°. Therefore, the temperature of the cooling water after absorbing the latent heat will be 60° + 26.3° = 86.3°. (The remainder of the rise

[1]Detroit Edison Company.

[1] "A Method of Heating with Refrigeration," HEATING AND VENTILATING, September, 1931, page 77.

[2] HEATING AND VENTILATING, September, 1931, page 78.

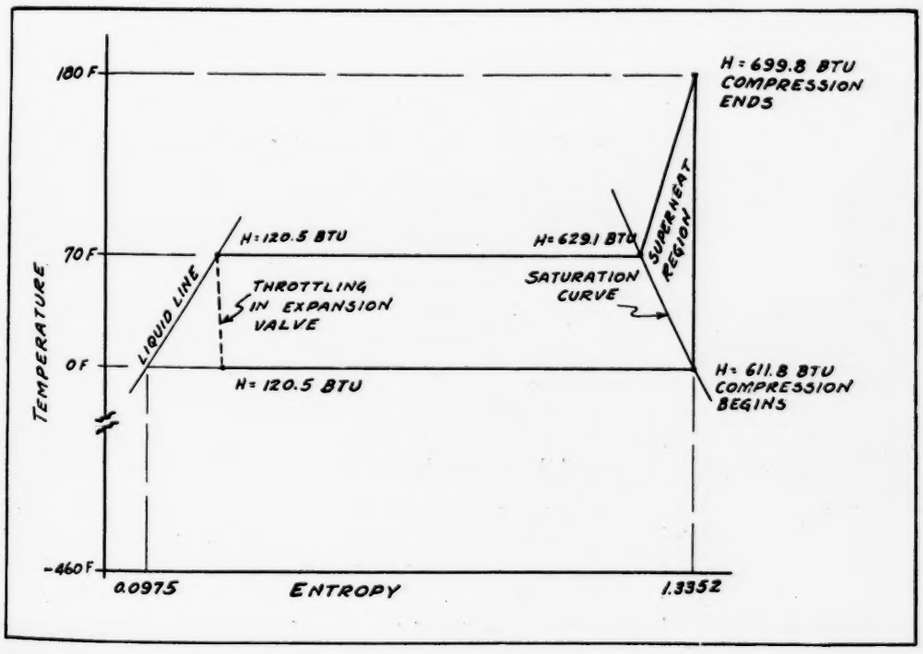


Fig. 1. Temperature-entropy diagram for conditions of original article.

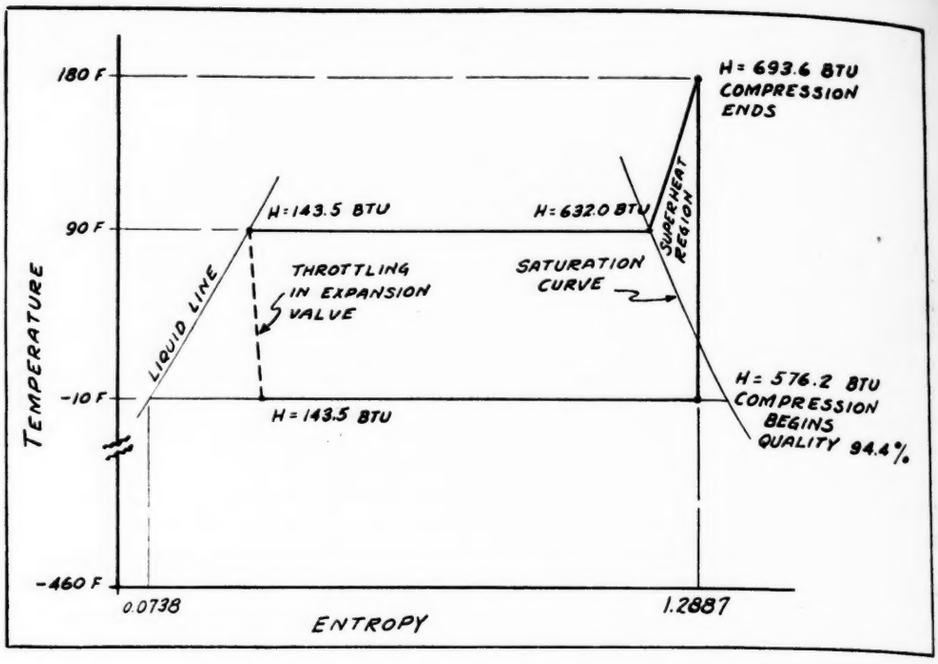


Fig. 2. Temperature-entropy diagram allowing for terminal temperature difference in heat transfer apparatus.

to 90° occurs during absorption of the heat of superheat of the ammonia.)

Obviously, water at 86.3° cannot, of itself, absorb heat from a body at a temperature of 70° and the cycle as given is impossible. Since the heat of superheat is relatively small, the largest portion of heat absorbed by the cooling water is the latent heat of the ammonia vapor, which must be absorbed at its saturation temperature. As a consequence, nearly all of the cooling water temperature rise occurs during the absorption of latent heat. If the total heat were absorbed at a constantly decreasing ammonia temperature, a counterflow condenser using cooling water from 60° to 90° could be employed. The fact was overlooked in the original example that most of the heat given up is the latent heat of evaporization which, under the assumptions, must be absorbed at 70° or below.

To remedy this situation it is necessary to increase the head pressure above the 128.8 lb. abs. specified, increase the quantity of cooling water, decrease the temperature of the cooling water entering the condenser, or employ a combination of these measures. The water temperature cannot be reduced below 60° because of the temperature of the air being handled. To increase the water quantity would decrease the outlet water temperature below 90°, which is certainly none too high if it is desired to heat air to 80°[3]. There remains then only the possibility of an increase in head pressure. In recalculating this cycle it will be just as well to introduce practicable temperature differences in the heating and cooling coils.

Let the following set of conditions be assumed, using ammonia as before:

Head pressure = 180.6 lb. abs., corresponding to saturation temperature of 90°.

Adiabatic compression to a temperature of 180° (the temperature of the end point of compression in original example).

Water temperature entering the condenser = 70°. This assumes 10° difference between air entering warming coil and water leaving.

Water temperature leaving the condenser = 90°. Assumes 10° difference between air leaving warming coil and water entering.

Brine temperature entering evaporator = 0°. Assumes 10° between air entering cooling coil and brine leaving.

Brine temperature leaving evaporator = —5°. Assumes sufficient circulation of brine to evaporate ammonia with only 5° drop in brine temperature.

Evaporator coil temperature = —10°. Assumes only 5° difference between the temperature of brine leaving evaporator and ammonia.

The temperature-entropy diagram with allowance for these temperature differences is shown in Fig. 2.

With these conditions,

Heat content of ammonia at end of compression	= 693.6 B.t.u.
Heat content of liquid ammonia at 90°	= 143.5 B.t.u.
Heat to warming coil	= 550.1 B.t.u.
Quality of ammonia at beginning of compression	= 94.4%
Heat content of ammonia at beginning of compression	= 576.2 B.t.u.
Heat of compression = 693.6 — 576.2	= 117.4 B.t.u.

Assume compressor efficiency = 90%, and motor efficiency at 90%. (It is believed that the 95% motor drive efficiency assumed in the original example is too high.) Motor input = $\frac{117.4}{0.90 \times 0.90}$ = 144.5 B.t.u per lb. of ammonia.

Considering only the compressor, the heat delivered to the building is 550.1 B.t.u. for each 144.5 B.t.u. input to the motor. The ratio of 3.8 to 1 compares with the ratio of 4.9 to 1 of the original problem.

[3]It is to be noted that to supply a building heat loss with air at 80° involves the circulation of a large volume of air. As calculated for the house considered later on in this discussion, the air circulated amounts to 2730 c.f.m. in a building volume of about 13,000 cu. ft. This is equivalent to 12.6 air changes per hour, and might result in an uncomfortable feeling from drafts. Apparently, the high efficiency resulting from the use of air at low temperatures would be undesirable from the comfort standpoint. If objectionable drafts are to be avoided, the volume of air circulated should be decreased with a corresponding increase in air temperature obtained at the expense of a decrease in cycle efficincy.

Figure 3 is a schematic diagram of the equipment for this cycle. This diagram is a rearrangement of Fig. 2 which appeared in the article to which reference was made.

Let calculations now be made to indicate the size of the equipment for an ordinary house of six or seven rooms so that a guess can be made as to the actual coefficient of performance, including fan and pump power, and the cost of the equipment for a specific case. The heat loss from such a house, even if well insulated, probably would approximate 60,000 B.t.u. per hr. on a 10° day. The weight of ammonia handled is then

$$\frac{60{,}000}{550.1} = 108.7 \text{ lb. per hr.} = 1.82 \text{ lb. per min.}$$

As a refrigerating machine the compressor would be rated at

$$\frac{1.82 \times (576.2 - 143.5)}{199.2} = 3.94 \text{ tons capacity}$$

The motor input is

$$\frac{1.82 \times 144.5 \times 778}{33{,}000} = 6.19 \text{ hp.}$$

The amount of cooling water circulated in the condenser and warming coil A is

$$\frac{1.82 \times 550.1}{90 - 70} = 50.0 \text{ lb. per min.}$$

If a friction loss of 10 ft. be assumed, together with 50% pump efficiency and 50% motor efficiency, the power consumption of the water circulator is

$$\frac{10 \times 50.0}{30{,}000 \times 0.50 \times 0.50} = 0.06 \text{ hp.}$$

The amount of air handled in the warming coil is

$$\frac{1.82 \times 550.1}{0.24\ (80\text{–}60)} = 209 \text{ lb. per min.} = 2730 \text{ c.f.m.,}$$

and the air friction loss would be at least one inch of water. With a 50% fan efficiency and 75% motor efficiency the input to this fan motor is

$$\frac{2730 \times 0.000157 \times 1}{0.50 \times 0.75} = 1.14 \text{ hp.}$$

The amount of brine circulated is

$$\frac{1.82 \times (576.2 - 143.5)}{0.78\ (0 - (-5))} = 201 \text{ lb. per min.}$$

If the friction loss is 10 ft. and the pump and motor efficiencies are taken the same as for the water circulator, the motor input will be

$$\frac{10 \times 201}{33{,}000 \times 0.50 \times 0.50} = 0.25 \text{ hp.}$$

The air circulated through coil B is

$$\frac{1.82\ (576.2 - 143.5)}{0.24\ (10 - 5)} = 655 \text{ lb. per min.} = 7800 \text{ c.f.m.}$$

With a one-inch of water friction loss, 50% fan efficiency and 85% motor efficiency, the input to this fan is

$$\frac{7800 \times 0.000157 \times 1}{0.50 \times 0.85} = 2.88 \text{ hp.}$$

The total power input is then

$$6.19 + 0.06 + 1.14 + 0.25 + 2.88 = 10.52 \text{ hp.}$$

and the coefficient of performance is

$$\frac{60{,}000}{10.52 \times 2545} = 2.24,$$

as compared with the value of 4 hoped for in the previous article. Since the electrical and mechanical losses which occur at temperatures above 70° will actually help to keep the house warm, they may be added directly to the heat delivered by the warming coil A. They do not possess any thermodynamic advantage. Making this correction we have as a final performance

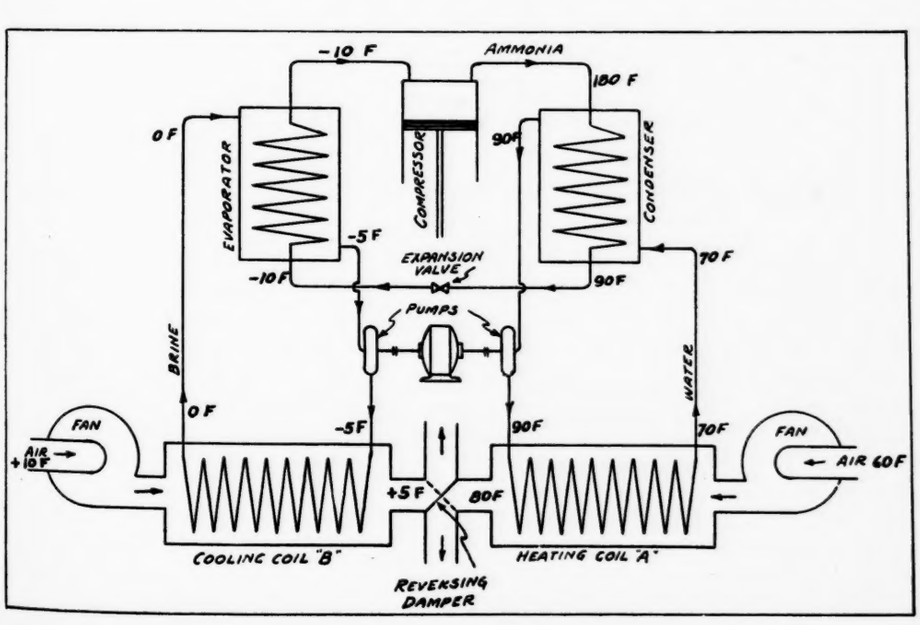


Fig. 3. Schematic diagram of equipment for cycle as calculated by author.

coefficient, C.P. =

$$\frac{60{,}000 + (0.19 \times 6.19 + 0.750 \times 0.06 + 0.625 \times 1.14)\ 2545}{\dfrac{10.52 \times 2545}{64.920}} = \frac{10.52 \times 2545}{10.52 \times 2545} = 2.42$$

The amount of surface in the warming coil A is estimated at 2480 sq. ft., while that of coil B is estimated at 1950 sq. ft. For the purpose of calculating surface requirements and costs, these coils have been assumed similar to the coils of generator air coolers. The combined cost of these two coils would be $2,500 to $3,000.

The compressor on this job would be worth about $800. The pumps, motors and fans would cost about $600. The condenser and evaporator would cost about $500. The total equipment cost would then be approximately $4,900, with the cost of installation extra.

Operating cost other than fixed charges and maintenance will vary with the price paid for electricity. The following table shows the equivalent coal cost for heating at different electric rates.

Cost of electricity, cents per kw.-hr.	Equivalent cost of 13,000 B.t.u. coal, dollars per ton
0.5	7.80
1	15.60
1.5	23.40
2.0	31.20
2.5	39.00

This table assumes 50% overall efficiency of a heating system using coal, and is based on coefficient of performance equal to 2.42 for the heat pump. Actually, during the milder weather the heat pump will operate more efficiently than during extreme weather, and the seasonal performance coefficient will be somewhat greater than 2.42. In the same way the cost of operation as compared with the use of coal will be lower than that given in the table.

In this example no attempt has been made to determine the most economical conditions for the apparatus. Larger temperature differences throughout the system would reduce the size and cost of the four heating surfaces. On the other hand, the efficiency of the cycle would be reduced thereby, and the operating cost would be increased. The compressor and driving motor would be correspondingly larger. Increasing the size of the heat exchangers reduces the temperature difference, but increases the cost. The compressor and motors would be somewhat smaller and less expensive and the whole cycle would be more efficient thermally. Perhaps a more economical layout would be obtained by designing the system for service on an average day for the heating season and installing simple resistance heaters to assist in warming up and to act as boosters during the more severe weather.

In the theoretical efficiency formula $\frac{T_1}{T_1 - T_2}$ it is to be noted that the smaller the difference $T_1 - T_2$ the greater will be the efficiency. Therefore, in mild climates this scheme of heating should work to much better all-round advantage than in the sample just calculated.

The original article stated that the greatest possibilities for usefulness appear to be in air warming rather than in air cooling. Be that as it may, it is believed that the majority of people living in climates where the temperature ranges from 10° to 90° would derive most satisfaction from such apparatus for air cooling, trusting to simpler and less expensive methods for keeping warm during the winter months. Of course, with the apparatus installed for air cooling it might well be used for air warming if justification for the extra operating expense as compared with other methods can be found.

Development of this system of heating to a place of commercial importance depends upon the perfecting of compact, effective and inexpensive heat transfer apparatus. Suitable compressors, pumps, fans, and motors have been available for years. Use of some refrigerant other than ammonia might work out to better advantage, or the use of an entirely different form of heat pump not requiring such elaborate heat transfer apparatus should prove more desirable. As an example of the latter, the compression of air and subsequent expansion, after giving up its sensible heat in one set of coils corresponding to the ammonia condenser, results in good thermal efficiency, in some cases better than that obtainable with ammonia. The apparatus would still be bulky and complicated, but considerably simpler than that which has just been discussed.

Although much remains to be done in the way of finding the best refrigerant for use in such a cycle, it is believed that the development of equipment requires more concentration of effort at the present time.

Advantages of Ice for Cooling Homes

IN my opinion, it will be far more feasible to use ice (than to use mechanical refrigeration) for cooling the homes. Reasons for this statement are:

First of all, the mechanical unit involves a large investment,—probably four times the investment necessary if ice is used. Remember, too, that this investment is utilized at a maximum of only one hundred twenty days a year, and the rest of the time it lies idle. Second, there is a much higher depreciation on compressors than there would be on an ice melting tank. Third, the maintenance cost,—including repairs and service charges because of the more complicated equipment and because of the greater technical knowledge required for service work,—will be considerably higher than the corresponding cost on an ice melting tank. Furthermore, the heat efficiency, or rather the efficiency of making ice by a so-called ice plant in the home is bound to be less than in the commercial ice plant of the locality. The commercial ice plant can afford to put up and maintain ice storage space of sufficient capacity to care for community requirements during the home cooling season. The famous load factor enters in with all its viciousness, and there seems to be no question but that ice can be made far more efficiently in the larger commercial plant than in the small house unit.—Professor Donald B. Keyes, in *Ice and Refrigeration.*

A high school dining-room with the ceiling treated with sound absorbent material.

The Solution of Noise Problems

By J. S. PARKINSON[1]

IN nearly all professional problems diagnosis is simpler than cure. This statement is no less true in cases involving noise or vibration. As a matter of fact, it has always been one of the writer's grievances that papers on noise and noise elimination were prone to deal almost entirely with methods of measurement and analysis, with remedies and cures left entirely out of the picture.

It must not be supposed, however, that nothing is known of remedies and cures. Several large organizations maintain research staffs expressly directed to study such problems, and from time to time new information is added to the growing knowledge of the subject. The following discussion will be devoted to a summary of the results of such investigations, with such general conclusions as seem pertinent.

We have seen earlier in this discussion that sound problems may be attacked in two ways. Either the source may be relocated, redesigned, or in some way modified so as to render it unobjectionable; or else steps may be taken to prevent the sound from reaching human ears. Sound or noise is seldom objectionable in itself, unless it indicates friction or lack of balance in the source.

Much may be done in the design and layout of work areas where noise makers are known to exist. Several modern manufacturing plants have had complete noise surveys made previous to mapping out machine locations. The data thus obtained were used to protect those workers of whom special skill or concentration was required, and to help locate the noise-producing operations in areas where means of noise elimination were most readily available.

It has been emphasized that noise is always produced by some vibrating surface. The existence of this surface is not always obvious, but if it can be located, a first major step in noise elimination has been accomplished. The conditions under which a vibrating body produces sound are special, and any considerable variation from those conditions renders the sound source ineffective, as any loud speaker manufacturer will be the first to testify. If, therefore, the vibrating surface can be damped, or stiffened, or perforated, or muffled, etc., we already have the beginning of a solution.

The problem of a noisy refrigerator is an excellent example. The fundamental source of the noise lies in the moving parts of the motor and compressor, but a good deal of the noise which reaches the ears of the listener comes from the vibration of the metal sheets which form the walls of the machine housing. If these sheets were made heavier, or if cross bracing were employed, or if a soft, resilient material were applied to their inner faces, a considerable part of the vibration would be eliminated and, consequently, a considerable part of the noise. The same type of reasoning may be employed to the design of a fan housing.

There are several types of unit heating or condi-

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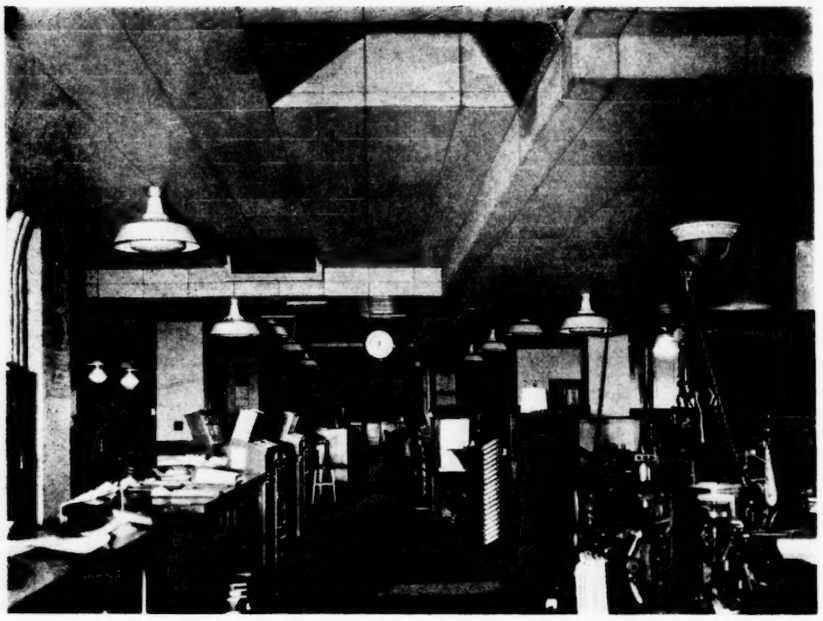


Acoustical tile installed in a newspaper plant. Several tile have been removed and bolts and thumb screws provided so that they can be removed and replaced to make vent ducts and conduits readily accessible.

tioning devices on the market which offer a similar problem. Moving parts are necessary in the motors or fans, but the vibration resulting from such sources might never be objectionable if suitable precautions were taken to prevent it from escaping into the air. Steps should be taken in such cases to break all connections between the source of vibration and any possible agencies which might transmit the energy into the air. If such agencies exist, in the form of a large panel, shields, baffles, etc., steps should be taken to minimize their vibration in some way. Such measures are usually particularly effective in abating the nuisance, because their result is to eliminate the major part of the high frequency noise. As was mentioned earlier, the higher frequencies are not only more annoying than the low ones, but also they are much more readily distinguishable. In the average residence or workplace there is always present a certain amount of background noise. Because this background noise usually comes from outside the room, it is likely to be of low frequency, and will mask other low frequencies to a considerable extent.

From time to time schemes are suggested for destroying noise energy in the air by some type of interference. These schemes are nearly always based on the neutralizing of one train of sound waves by another train of waves of the same frequency and exactly out of phase. The high pressure areas in the one wave train exactly coincide with the low pressure areas in the other set of waves, and the net result under ideal conditions may be almost complete balance. However, this type of interference can exist only under rather special conditions. The waves must be of a single frequency, or at best a very narrow band of frequencies, and the existence of harmonics or (as is more often the case in noises) of non-harmonic overtones will quite defeat the experiment. Furthermore, such a method of noise elimination can only be attempted in places where the noise can be confined to some restricted channel. It is quite out of the question in an open space.

How then, it may be asked, can noise be attacked if it does escape into the air? The answer is that it may be either deflected or absorbed. These two operations are essentially different and must be taken up separately.

Sound absorption, to take the latter first, is in reality a misnomer. Sound energy can no more be absorbed than mechanical or electrical energy. Like all forms of energy, it is indestructible, and to do away with it one must convert it into some other form of energy. In most so-called sound absorbers, this process consists of a conversion into either heat or mechanical energy. To the average laymen such an operation is rather mysterious. Sound is passing through a duct or tube. Now, let the walls of this duct or tube be lined with a certain special kind of material, and lo! sound no longer is heard. As a matter of fact, however, this state of affairs is no more mysterious than the absorption of light or heat. Put a hundred watt light in a room whose walls are painted white, and there is plenty of light for everybody. Now paint one wall black and there is a considerable diminution in the total amount of light available. Paint the entire room black and the light will be a spot of illumination in the darkness. Where has the light gone? There is just as much energy proceeding from the source as before. The black walls *absorb* light energy instead of reflecting it.

That there are similar materials which do the same thing to sound is a matter of common experience. How much quieter a house is after it is furnished; what a contrast it is to the bare re-echoing rooms previously encountered. What a silent, muffled place the average closet is, particularly if there are clothes or wraps or linen lying about. The actual physical processes which take place are less familiar.

We remember that sound waves consist of a series of alternate condensations and rarefactions; first a section which is at higher pressure than the normal air pressure, and then a section which is lower, etc. These air vibrations are directed in a definite manner. They have a definite order of progression and maintain a fixed relation to one another. When such a train of waves strikes a hard impervious surface, each wave in turn is reflected and they stream out into the room in the orderly manner in which they arrived. If, how-

ever, this surface is soft and resilient and porous, the waves undergo quite a different process. Each wave has a sort of activity on the part of the molecules which happen to lie within the area of the wave at the moment. These molecules receive a new kind of vibratory energy which they did not have before.

Now, suppose that these molecules lie very close to the surface of the sound absorbent material. The advancing pressure of the wave may carry them into the interstices of the material, or at least against the yielding surface. Some of the vibratory energy which they have just received will be lost in friction against the fibres or cell walls of the porous material. Some more of this energy will be lost in pushing against the yielding surface. In many cases where the energy is not actually lost, it loses that directional characteristic which makes it essentially sound. It may be metamorphosed into a sort of random vibration which will manifest itself thereafter as heat.

As a result, when the train of waves attempts to leave this surface to make way for its successors it finds that it has been stripped of some of its energy, and that its capability for producing the sensation on the ear drum which we identify as sound is considerably impaired. When this process has taken place a number of times there will be a considerable loss in sound energy. Either in a room, or in a tube or duct, such a succession of reflections will of course take place rapidly. Sound travels 1100 ft. per sec. at normal room temperatures, or more than 700 m.p.h.

The sound absorbing properties of a material are expressed by what is known as its absorption coefficient. This absorption coefficient is the ratio of the amount of sound energy *absorbed* in a single reflection to the total quantity of incident energy. The absorption coefficient is often expressed as the ratio of sound absorbed to the amount which would pass through an equal area of open window.

It must be remembered that the absorption coefficient of a material as ordinarily given is for random incidence. If a wave strikes perpendicular to the face of the material, the effect is quite different from that produced by a wave striking at an acute angle. Sound passing through a duct lined with sound absorbent material will in most cases strike the material at a very acute angle, and there is reason to suppose that under such circumstances the material is more efficient than as ordinarily quoted.

This somewhat lengthy discussion has been necessary because of the extended use of sound absorbent materials in problems of quieting and noise control. In many cases, all precautions are fruitless to prevent the sound from escaping into the air, and the sound absorbent material acts as a sort of last line of defence. It may be placed on the ceilings or walls of rooms to reduce reflections and to lower the total sound level built up in the room. It may be inserted on the inside of fan and machine housings or under the hoods or dashboards of automobiles, to reduce the sound escaping from these sources. It has been used in several types of window ventilating devices to make it possible to admit air, without at the same time permitting outside noise to pass. In many instances it is employed as a lining for ventilating ducts to avoid the telegraphing of sound through the system. There are many more uses, under typewriters or office machinery, etc., but there is not space here to go into such a discussion. The fundamental fact is that sound absorbent materials in their various forms represent the most important single means of combating noise.

Often where sound cannot be absorbed it may be deflected. This is not usually true, of course, where the sound originates in the same room. It often happens, however, that walls or partitions may be interposed in the path of the sound, and it then becomes important to know just what properties such a wall or partition must possess to be an effective sound insulator.

The first essential is rigidity. Sound is usually transmitted by the vibration of the wall as a whole, or by the communication of the vibration from one side to the other in the case of a double wall possessing some structural ties. Mass and rigidity are necessary to prevent this kind of action. The breaking of structural contact is also important, and this applies to direct mechanical transmission as well as to problems of air-borne sound. A wave passing through a uniform medium is partially reflected each time it encounters a new medium. One commercial system of sound isolation employs metal chairs and hangers lined with

Acoustical treatment in a Memorial Union building in a Western university.

felt to provide structural ties and supports, so that sound in passing from one part of the structure to another must find its way through this barrier of felt each time. Machine bases and platforms may be constructed on felt supports in a similar fashion or may be rested on cork or rubber combinations.

Another well-known commercial system employs spring supports and fasteners relying on the resilient action of these springs to resist the passage of sound.

It could be mentioned that a sound absorbent material is not often of itself a good sound insulator. Thus, if a ventilating duct were to be constructed of some one of the porous sound absorbent materials which are in general use, this material would have to be backed with a hard and rigid material in order to prevent sound from escaping from the duct and being short-circuited in that way.

There has been, perforce, little directly useful data given in these articles to heating and ventilating engineers. The design of equipment must always be an individual problem depending on the conditions to be encountered. It has not been possible to do more than point out certain general rules.

In the design of ventilating systems likewise it is necessary to confine the data to generalities. The central plenum chamber, if one is used, should be as far as possible from occupied spaces. If it contains any noisy equipment, or if it is large and reverberant, it should be treated with sound absorbent materials. Fan motors and fans should be mounted on anti-vibration platforms so as to prevent the transmission of sound to the building structure. The fans or blowers should not be directly connected to the duct system, the tie being broken by the use of flexible canvas connections or the like. Fan spuds should be as low as practicable, to eliminate this source of sound.

Ventilating ducts should not serve more than one room, as transmission between rooms is an important consideration. If ducts are run side by side they should not have a common wall, and should never be directly anchored to one another. If sound absorbent material is used it should be placed as close as possible to the sound source to be most effective. Ducts should likewise be designed to be long and narrow—widely rectangular in cross section rather than square. The closer to the sound absorbent material the air passes, the more effective the sound absorbing action will be. Often a nest of small ducts set in a honeycomb arrangement within the larger one will act as an effective sound filter.

It must be remembered also that the effectiveness of a sound-absorbent duct lining increases in a diminishing scale. The second ten feet have much less effect than the first ten, etc. There are formulas by which this reduction in loudness can be computed, although they are somewhat too intricate to discuss here.

Sharp right-angle bends are useful as a further means of diminishing sound transmission through a duct. Several such bends may be equivalent in effect to a number of feet of straight lined tube.

A Common Humidity Error

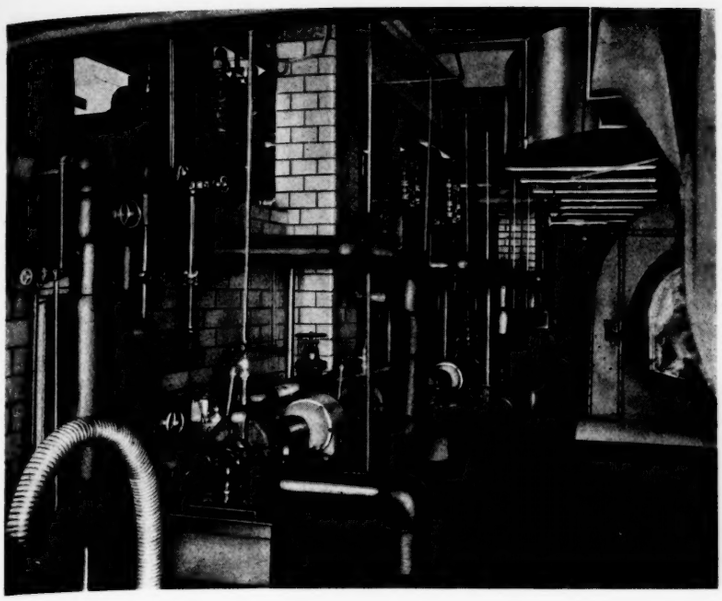
MANY people who should know better seem to have surprisingly vague, if not even confused, ideas about humidity, and where there is much smoke there generally is some fire. Those who have to do with the measurement of humidity would insist, if questioned, that they know perfectly well what the terms "absolute humidity" and "relative humidity" properly mean. Perhaps they do; nevertheless many, if they should condescend to answer at all, would say, in substance, that absolute humidity is the mass of water vapor present per unit volume of the air, and relative humidity the ratio of the amount of water vapor present to the amount necessary to saturate the air at the same temperature.

That sounds familiar and orthodox, but it reveals confusion at best, for the air has nothing to do with either absolute humidity, properly defined as the mass of water vapor per unit volume (of space, not air), or relative humidity—the ratio of the mass of water vapor present per unit volume (of space) to that which would saturate a unit volume at the same temperature. Be certain not to add "and same pressure," which we sometimes hear, for that refers to the atmosphere, which, as just stated, has nothing to do with the phenomenon in question.

There is, however, one very useful humidity concept that does involve the air, namely, the mass of water vapor per unit mass of humid air. This is called "specific humidity."

But entirely apart from definitions we often see and hear expressions about the air taking up water vapor and about the great avidity of warm air for water vapor. Now, as a matter of fact, the air does not "take up" water vapor—it is not a sponge; and warm air has no avidity, chemical or other kind, for water vapor. All the air does in this connection is to slow down the rate of evaporation and diffusion. It is not the air but the space, air or no air substantially alike (a shade better without the air), that has the vapor capacity. Neither is it the temperature of the air but the temperature of the vapor (again air or no air) that determines the amount of water vapor per unit volume necessary to produce saturation.

Most of us say the air takes up water vapor. Let us forget it, if we can, and say space instead, as that is what we mean, if we understand the phenomenon aright.—W. J. Humphreys in *Monthly Weather Review*, July, 1931.



Cooling Capacity Calculations with Recirculated Air

By ANDRE MERLE †

SOLUTION of problems involving the heat quantities necessary to accomplish air cooling as a part of air conditioning installations need be neither long nor complicated if one takes advantage of tabular data and of the constants available. True, it is quite possible to compute the quantities by finding the sensible and latent heat separately and then adding them together. Use of what may be termed the wet bulb temperature method greatly shortens the work involved. Tables containing the essential data on the properties of air are also very helpful as timesavers.

Use of the wet bulb temperature in making calculations is justified when it is recalled that the wet bulb changes with changes of total heat in the air and moisture mixture. In other words, the wet bulb temperature is a measure of the total heat. Because of this, tables like Table 1 are useful. This table shows the total heat per pound of air above 0° F., at wet bulb temperatures from 32° to 100°. Interpolation may be made between the even degrees.

Table 2 gives the moisture content of saturated air at temperatures from 32° to 100°. This table is also useful in making computations. Interpolations may also be made between the even degrees.

Since the wet bulb temperature is constant so long as the total heat is constant, and since the amount of this heat is known from Table 1 within the ordinary ranges, the method consists of tracing the changes of wet bulb temperature, and noting the corresponding changes in the heat quantities.

Where no recirculated air is used this method can be used directly, but where recirculation is practiced the application can be made by using a trial and error method to find the dew point depression and the quantity of dehumidified air.

Fig. 1 illustrates diagrammatically a much used method of handling the air at the washer. The air which has passed through the conditioned space is brought to a point near the washer and is split into two parts. Part mixes with the outside air, passes through the washer and is cooled, while the other part is simply recirculated without being processed by the washer. The dehumidified air consists of the outside air and the return air.

As the dehumidified air passes through the washer there must be removed from it an amount of moisture equal to that given up by the people in the conditioned space and that brought in by infiltering air. The apparatus dew point must be fixed low enough to permit doing this with the amount of air being dehumidified.

The following example illustrates the application and makes the method of procedure clear.

> *Example:* **Assume a room of 120,000 cubage with 200 people, which is to be cooled to 80° dry bulb and 50% relative humidity with an outside condition of 95° dry bulb and 75° wet bulb. The computed heat gain under these conditions is 5600 B.t.u. per min. due to people, lights, sun effect, infiltration, building transmission, fan power, and incidentals. The arrangement shown in Fig. 1 is to be used.**

Step 1. Determine and tabulate the conditions of the inside and outside air.

TABLE A

	Dry Bulb	Wet Bulb	Relative Humidity	Dew Point	Moisture gr./cu. ft. (at D.P.)
Outside	95	75	39	67	7.241
Inside	80	67	50	59.5	5.650

Step 2. Fix tentatively a dew point depression, and approximate the quantity of dehumidified air to be handled.

The dew point depression below the maintained dry bulb can be approximated by recalling that the apparatus dew point must be somewhat lower than that of the room air. From Table A the room dew point is 59.5°, and the difference 80 — 59.5 = 20.5. A trial dew point may then be taken at 23°.

depression

†Chief Engineer, Tiltz Air Conditioning Corporation.

Table 1.

TOTAL HEAT TABLE

Temp. °F.	Total Heat	Temp. °F.	Total Heat	Temp. °F.	Total Heat
30	10.9	54	22.4	78	40.5
31	11.3	55	23.	79	41.5
32	11.8	56	23.6	80	42.5
33	12.2	57	24.2	81	43.5
34	12.6	58	24.8	82	44.5
35	13.	59	25.3	83	45.6
36	13.5	60	26.	84	46.7
37	13.9	61	26.6	85	47.8
38	14.4	62	27.3	86	49.0
39	14.9	63	28.1	87	50.2
40	15.3	64	28.8	88	51.4
41	15.8	65	29.5	89	52.7
42	16.3	66	30.3	90	54.0
43	16.8	67	31.	91	55.3
44	17.3	68	31.8	92	56.7
45	17.8	69	32.6	93	58.0
46	18.3	70	33.5	94	59.4
47	18.8	71	34.3	95	60.9
48	19.3	72	35.2	96	62.6
49	19.8	73	36.	97	64.1
50	20.3	74	36.8	98	65.6
51	20.8	75	37.8	99	67.2
52	21.3	76	38.7	100	68.8
53	21.8	77	39.7	101	70.5

Table 2.

MOISTURE TABLE

Temp. °F.	Grains per cu. ft. air (saturated)	Temp. °F.	Grains per cu. ft. air (saturated)	Temp. °F.	Grains per cu. ft. air (saturated)
30	1.935	78	10.277	54	4.685
31	2.022	79	10.601	55	4.849
32	2.113	80	10.934	56	5.016
33	2.194	81	11.275	57	5.191
34	2.279	82	11.626	58	5.370
35	2.366	83	11.987	59	5.555
36	2.457	84	12.356	60	5.745
37	2.550	85	12.736	61	5.941
38	2.646	86	13.127	62	6.142
39	2.746	87	13.526	63	6.349
40	2.849	88	13.937	64	6.563
41	2.955	89	14.359	65	6.782
42	3.064	90	14.790	66	7.009
43	3.177	91	15.234	67	7.241
44	3.294	92	15.689	68	7.480
45	3.414	93	15.155	69	7.726
46	3.539	94	16.634	70	7.980
47	3.667	95	17.124	71	8.240
48	3.800	96	17.626	72	8.508
49	3.936	97	18.142	73	8.782
50	4.076	98	18.671	74	9.066
51	4.222	99	19.212	75	9.356
52	4.372	100	19.766	76	9.655
53	4.526	101	20.335	77	9.962

Tables courtesy Tiltz Air Conditioning Corporation

On the basis of the tentative dew point depression the quantity of dehumidified air is:

$$\frac{5600 \times 56}{23} = 14{,}000 \text{ c.f.m.}$$

where 56 is the number of cu. ft. of air raised 1° by one B.t.u.

Step 3. Using this quantity of dehumidified air, determine the amount of moisture to be removed due to the people and to infiltering air.

The moisture per person per hour may be taken as 0.1 lb. On this basis the moisture due to people is:

$$\frac{200 \text{ people} \times 0.1 \text{ lb.} \times 7000 \text{ gr. per lb.}}{14{,}000 \text{ c.f.m.} \times 60 \text{ min.}} = 0.166 \text{ gr. per cu. ft., excess.}$$

The air is assumed to enter at the outdoor conditions and may be estimated at from one-half to one air change per hour depending on the tightness of construction. Taking it at one change per hour the calculation is:

$$\frac{120{,}000 \text{ cubage}}{60 \text{ min.}} = 2000 \text{ c.f.m.}$$

Dew point of infiltering air (Table A) = 67° = 7.241 gr. per cu. ft.
Dew point of room air (Table A) = 59.5° = 5.650 gr. per cu. ft.
Difference = 1.591 gr. per cu. ft.

$$\frac{1.591 \text{ gr.} \times 2000 \text{ c.f.m.}}{14{,}000} = 0.223 \text{ gr. per cu. ft., excess.}$$

The sum of these two moisture quantities just found is
$0.166 + 0.223 = 0.389$ gr. per cu. ft.

Step 4. In Table A note that the room air contains 5.65 gr. per cu. ft. The entering air should, therefore, contain $5.65 - 0.389 = 5.261$ gr. per cu. ft. In Table 2 find the temperature opposite this moisture content to be slightly above 57°. The apparatus dew point should, therefore, be set at this point with 14,000 c.f.m. of dehumidified air.

Comparing the apparatus dew point depression (80-57 = 23) with the assumed one of 23° shows that they check. Therefore, the quantity of dehumidified air, viz. 14,000 c.f.m., is sufficient.

In case the dew point depression as computed does not agree with the assumed dew point depression then a second assumption must be made. It is seldom necessary to make more than one computation, as in this example, for the assumed dew point can be made closely approximate to the computed one, except in unusual cases.

Step 5. Determine the weight of the dehumidified air.

With the dew point depression fixed this may be found as follows:

$$\frac{5600 \text{ B.t.u.}}{23° \text{ dew point dep.} \times 0.241} = 1000 \text{ lb. per min.,}$$

where 0.241 is the specific heat of air.

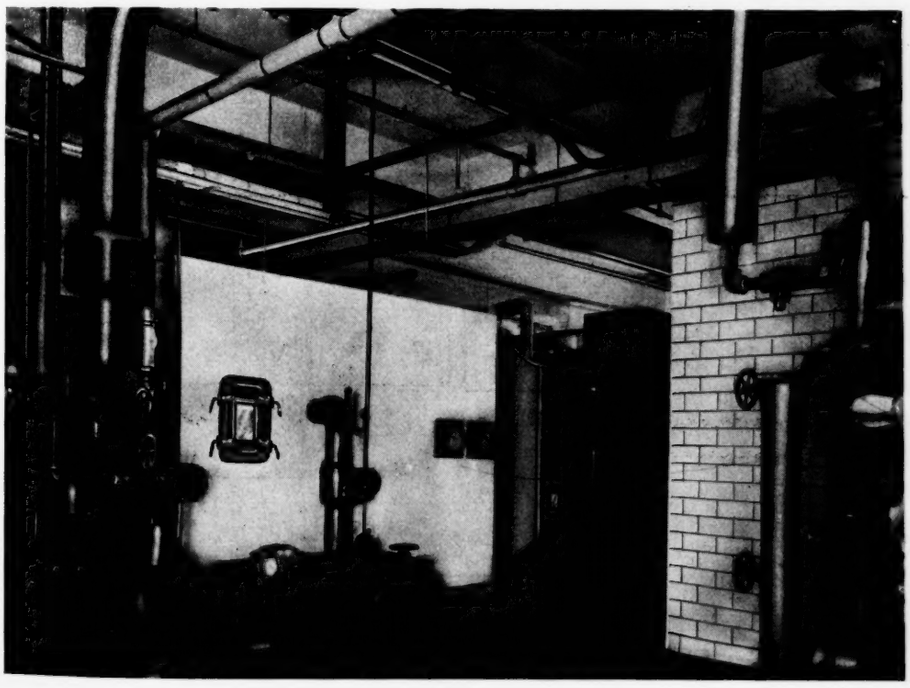
Step 6. Fix the dry bulb depression in accordance with current practice, or ordinance, or judgment, and find the volume of air to be handled through the system.

When the arrangement shown in Fig. 1 is used, one method is to fix the dry bulb depression—the difference between the dry bulb temperature of the room and the dry bulb temperature of the entering air — in accordance with the room height as shown in Table B.

TABLE B

Height	Temp. Difference
10 ft. and under	10°
15 ft.	12°
25 ft.	14°
30 ft. and over	16°

In this example assume that the room height is such that the dry bulb depression may be set at 11°. This fixes the dry bulb temperature of the entering air at



View of refrigerating pump room, Fox Film Laboratory, New York.

69°. Then the total air to be handled becomes:

$$\frac{5600 \text{ B.t.u.} \times 56}{11} = 28{,}000 \text{ c.f.m.}$$

With this quantity known the rate of air change can be computed:

$$\frac{120{,}000 \text{ cubage}}{28{,}000} = 4 \text{ min.}$$

Step 7. Determine the amount of outside air, return air, and recirculated air.

It is customary to allow for not less than 10 c.f.m. per person of outside air or not less than 25% of the total air handled. On this basis the amount of outside air in this example is

$$28{,}000 \times 0.25 = 7000 \text{ c.f.m.}$$

As the dehumidified air is 14,000 c.f.m. the return air must be

$$14{,}000 - 7000 = 7000 \text{ c.f.m.}$$

The difference 28,000 — 14,000 = 14,000 c.f.m. is the amount of recirculated air to be handled.

The air quantities and approximate weights are now known and can be tabulated as in Table C.

TABLE C

	Volume c.f.m.	Approximate Weight, lb.
Outside air	7000	500
Return air	7000	500
Dehumidified air	14,000	1000
Recirculated air	14,000	1000
Total air	28,000	2000

Step 8. Compute the total heat to be removed from the dehumidified air.

Outside Air

Total heat at outside air wet bulb of 75° (Table 1) = 37.8 B.t.u. per lb.
Total heat at 57° wet bulb (Table 1) = 24.2 B.t.u. per lb.

Total heat to be removed = 13.6 B.t.u. per lb.
13.6 × 500 lb. (Table C) ..... = 6800 B.t.u. per min.

Return Air

Total heat at room air wet bulb of 67° (Table 1) = 31.0
Total heat at 57° wet bulb (Table 1) = 24.2

Total heat to be removed = 6.8
6.8 × 500 (Table C) ..... = 3400 B.t.u. per min.

Since the dehumidified air is the outside air and the return air, the heat removed is

$$6800 + 3400 = 10{,}200 \text{ B.t.u. per min.}$$

Step 9. Compute the heat equivalent of the pump and motor power, and assume a value for pipe radiation.

This may be done by assuming a 7.5° rise in temperature of the spray water. Then,

$$\frac{10{,}200}{7.5 \times 8.33} = 165 \text{ g.p.m. to be handled.}$$

Against a head of 100 ft. and with 50% pump and motor efficiency the horsepower of the pump is:

$$\frac{165 \times 8.33 \times 100}{33{,}000 \times 0.50} = 8.33$$

This would call for a 10 hp. motor and it is customary to allow for the full equivalence of the motor, or

$$10 \times 42.5 = 425 \text{ B.t.u. per min.}$$

One method of assuming piping radiation is to allow this as being approximately equivalent to the pump heat equivalent. On this basis assume this loss to be 400 B.t.u. per min.

These two quantities combined are 400 + 425 = 825 B.t.u. per min.

Step 10. Find the total computed heat quantity. This is the sum of the results of Steps 8 and 9.

$$10{,}200 + 825 = 11{,}025 \text{ B.t.u. per min.}$$

Step 11. Allow for a safety factor, and compute the tons of refrigeration effect.

One practice is to allow 10% of the computed heat for capacities less than 5 tons and 5% if over 5 tons. On this basis the safety figure is:

$$11{,}025 \times 0.05 = 551 \text{ B.t.u. per min.}$$

The tons of refrigeration effect are found as follows:

$$11{,}025 + 551 = 11{,}576 \text{ B.t.u. per min.}$$

$$\frac{11{,}576}{200} = 57.9 \text{ tons.}$$

Step 12. Determine the spray water temperatures.

On the basis of a 7½° rise in temperature, the ingoing temperature can be fixed at 47½° and the outgoing temperature at 55° which is 2° below the apparatus dew point, and allows for the inefficiency of the dehumidifier.

Several checking rules should be noted. The amount of water cooled should not be less than 1 g.p.m. per 80 c.f.m. of dehumidified air. The range of temperature of the cooling water is usually between 5° and 8°. The velocity of air through the dehumidifier should not exceed 650 ft. per min. A quick tonnage check for estimating purposes is to allow 250 c.f.m. of dehumidified air per ton of refrigeration.

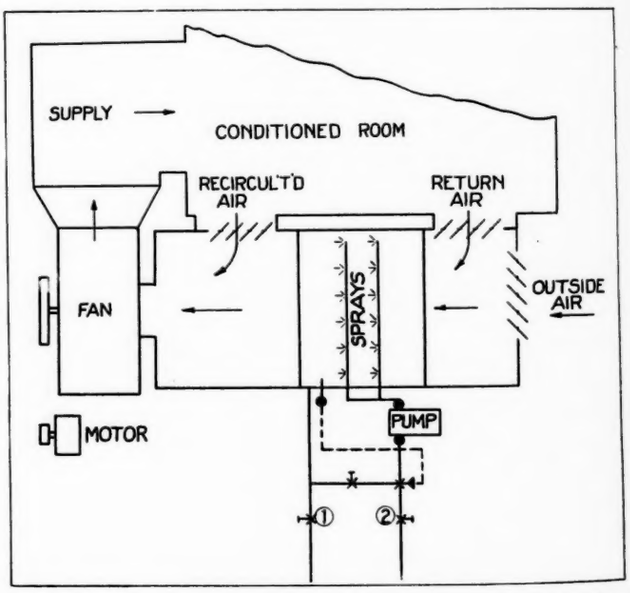


Diagram of arrangement at the washers when recirculation is used. The three-way valve which is controlled by a thermostat is shown. Valves 1 and 2 are closed when refrigeration machine is not in use.

Dividing 14,000 by 165 gives 85. The amount of spray water as computed in the example thus falls within the safe limit set by the rule.

Dividing 14,000 by 57.9 gives 242. If the rule of 250 c.f.m. of dehumidified air per ton of refrigeration effect were used the estimated tonnage would be 56. This illustrates how useful the overall rule of 250 c.f.m. per ton is in making preliminary estimates of refrigeration capacity. Its use greatly shortens the process but it cannot be depended on in all cases. The safe way is to make the longer solution if an accurate estimate is desired.

Heating and Ventilating Following Scientific Lines In Great Britain

WHILE British engineers and manufacturers have for long kept in touch with the latest developments in designing and utilizing heating and ventilating equipment, it is only lately that scientific systems have come to be regarded as necessities rather than luxuries in the United Kingdom. During recent years considerable research work has been done jointly by physiologists and engineers with the object of establishing comfortable and healthy conditions in large auditoriums, such as public halls, theaters, and the like. As a result air conditioning, combined sometimes with direct radiation, tends to become standard practice in such buildings.

A recent development is the endeavor to supply heat in such a form and manner as to keep an occupant of a room comfortable and healthy with the least expenditure of thermal energy. With this object in view apparatus is rapidly being designed and produced for practically demonstrating the results of this research. These appliances take the form of low, medium, and high-temperature independent or superimposed radiants, including those more or less embodied in the structure of the building. In this branch of heating, which is applicable to private houses, offices and schools, British practice differs appreciably from that of other countries, especially the United States. While the different climatic conditions are partially responsible for this difference, it is the opinion of J. Rogers Preston, past president of the Institution of Heating & Ventilating Engineers, that the future will prove that British engineers are moving in the right direction. The difference mentioned is that the American tendency is to employ convected heat through the medium of air circulated over concealed radiators, while the British practice is to utilize heat from direct radiation wherever possible.

The use of electricity for central heating through the medium of thermal storage is increasing in Britain, and manufacturers are producing equipment to meet the demand. As is well known, many electrical undertakings have a low power factor, which means that during certain periods of the day or night their boilers are under steam and their machines only running on light load. At these off-peak periods most companies will supply current at a cheap rate of 4 to 6 cents per unit. In utilizing electricity for thermal storage it is necessary to consider every job strictly on its merits, as those which may appear to be fairly similar may be found to vary considerably on examination of details and local conditions.

Heating engineers are paying greater attention to the design of boilers for heating, and some interesting new types are making their appearance. The increasing use of oil and gas as fuel and their comparatively high cost in Britain are largely responsible for this, for they rather lend themselves to high efficiency if the design of the boiler and all attendant equipment is right.

In oil-burning equipment British designers have long held the field for the larger units, but American makers highly developed the domestic market, with the result that many oil plants suitable for small installations are of American origin. However, there are a number of British burners now on the market in competition with the American units, while Continental apparatus has also entered the British field.

With regard to radiant gas heaters, of special interest are the recent researches which have disposed of the old idea that a gas fire merely warms or scorches the outer skin while leaving other parts of the body not directly exposed to the heat rays quite cold. In modern radiant gas heaters the quality of the heat given off has an increased proportion of short infra-red rays. These rays have a far more penetrating effect than the longer heat rays, and pass more readily through the skin, thus heating the blood stream and avoiding the scorching sensation otherwise produced. Therefore, as the radiation from the domestic gas heater is modified so as to contain a greater proportion of visible and short infra-red rays, its hygienic quality is improved. The penetrative properties of the rays from a new heater were recently demonstrated. A fine hypodermic needle was converted into a thermocouple, the needle being inserted lengthwise under the skin until the point was in the neighborhood of the blood capillaries underneath. It was shown that subcutaneous temperatures considerably higher than the normal blood heat could be reached without the sensation of excessive scorching of the surface of the skin.

The many heating appliances featured at the British Industries Fair this year testified to the remarkable advances that have lately been made in radiator design in the United Kingdom. They brought home the fact that radiators need no longer be unsightly objects, but can be as attractive and colorful as any other piece of household furniture. There is, however, a growing tendency to conceal them by means of handsome guards or grilles of perforated metal; and this tendency is carried still further in systems of concealed heating in which the metal skirtings and panels are quite unnoticeable.

Results of Tests on Radiant Heating Installations

By T. NAPIER ADLAM†

In this, the concluding article by Mr. Adlam on radiant heating, the author describes the apparatus used in England to measure the results obtained with different methods of heating, and presents data reported by British investigators as to the results of several tests on radiant heating installations in schools and factories

BRITISH heating engineers enjoy the advantage of receiving valuable help from two governmental agencies, viz.: the Medical Research Council and the Department of Scientific and Industrial Research.

The Industrial Health Research Board, working under the Medical Research Council, has made some investigations on comfort conditions in schools, factories and other buildings. In some of their studies the buildings were heated by radiant methods, and I would like to present some of their findings.

The Department of Scientific and Industrial Research has studied heating problems and has the resources of the Building Research Station at Garston to draw on. During the course of these studies some interesting measuring apparatus has been developed.

These two bodies are now working in collaboration, and reports of the results appear from time to time as pamphlets or as papers presented before the British Institution of Heating and Ventilating Engineers.

†Consulting Engineer, Bethlehem, Pa.

Description of Measuring Apparatus

Before considering the studies themselves and the results obtained, a few words about the nature and function of the measuring instruments seem desirable as some of these are rather distinctive.

Moll thermopiles connected to Cambridge and Paul dead-beat galvanometers have been much used as laboratory instruments for determining surface temperatures. These are well known instruments and require no explanation. Surface temperatures of radiant heaters, walls, glass, and of the skin have been taken by the use of these thermopiles. Ordinary mercury-in-glass thermometers are regarded as unsuitable for such measurements, but have been used for approximate work.

Another instrument considered very useful by some English engineers is the kata-thermometer. It is a specially built thermometer having a very large bulb and stem. The bulb is usually about 5/8 in. in diameter and 2 in. long. The stem is graduated over the range of 95° to 100° F.

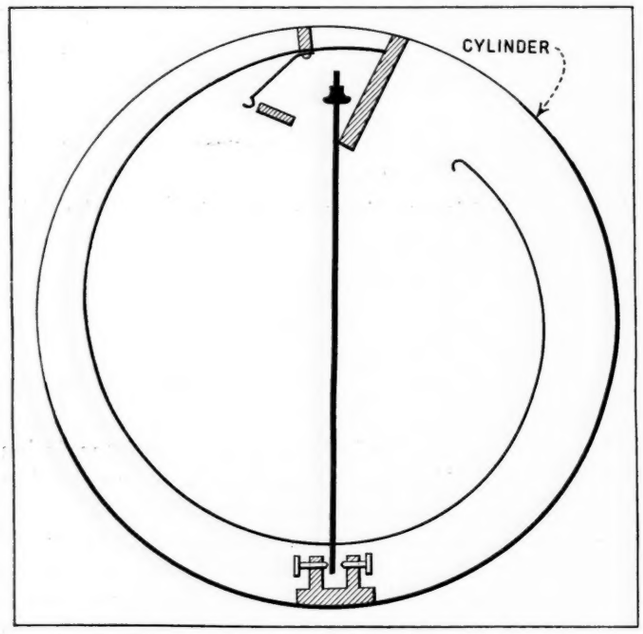


Fig. 1. Thermostatic mechanism in the eupatheostat

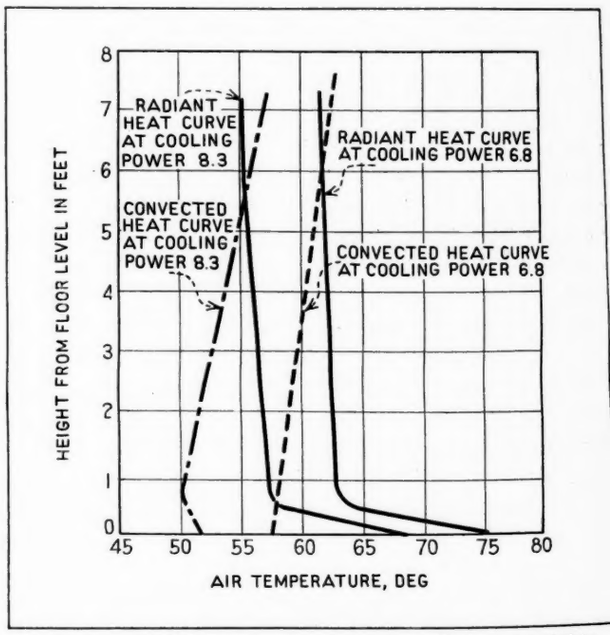


Fig. 2. Relative air temperatures, at different heights, for both radiant and convected heat from tests made in classrooms

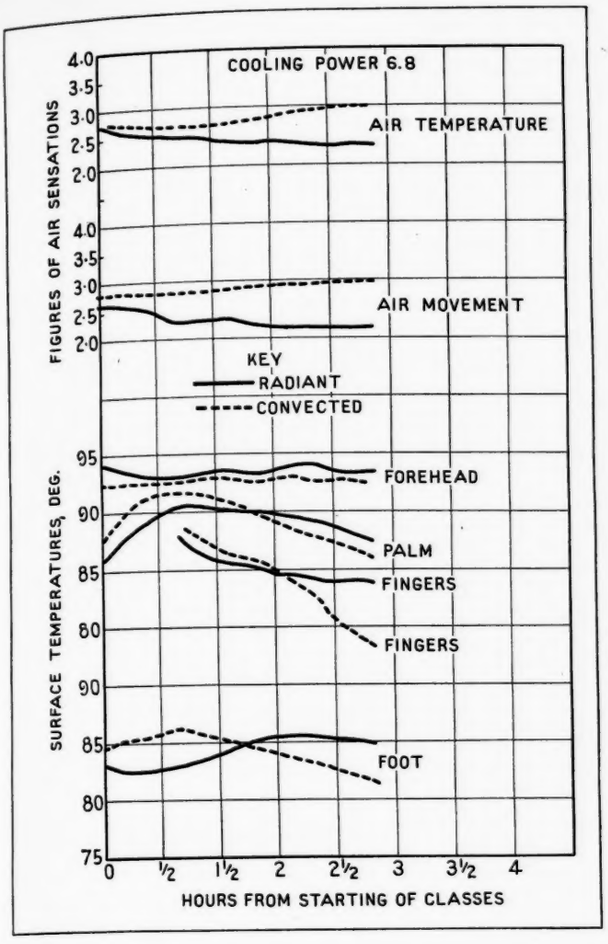
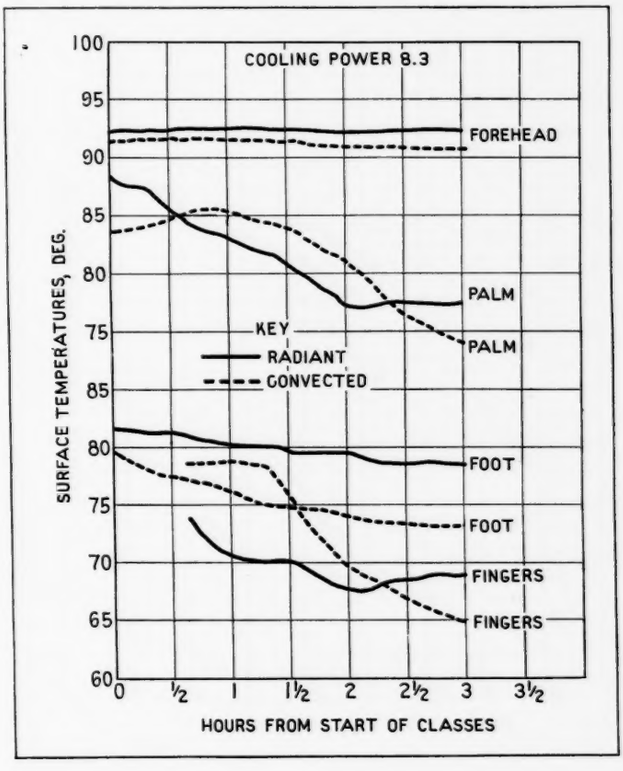


Fig. 3. (Left) Relative skin temperatures from tests comparing results from convected and radiant heat, with a cooling power of 6.8

Fig. 4. (Below) The same comparison as in Fig. 3 with a cooling power of 8.3



The procedure in using it consists of heating the bulb until the instrument indicates a temperature slightly above 100°. It is then placed in the position where an observation is desired and the time required for the mercury column to fall from 100° to 95° is noted. The air temperature is also noted at the same time and place.

The time required for the column to fall depends on the temperature difference between the bulb of the thermometer and the air, and on the rate of air movement. The instrument has been regarded as being particularly useful for measuring the cooling power of air and for determining low velocity air movements.

Some have regarded the kata-thermometer as simulating the human body and feel that its rate of heat loss to the air can be taken as similar to that of the body. It has consequently been looked on as a sort of comfort meter on the assumption that the rate of heat loss to the air is a measure of the feeling of comfort. Wet kata-thermometers have also been used on occasion for similar purposes.

The final figure obtained when using this instrument is known as the *cooling power*. This is a numerical scale which permits the practical use of the instrument. The Industrial Health Research Board has made use of this cooling power standard in many of its investigations and its reports refer to those numbers in describing the air conditions instead of using air temperatures.

Another instrument made use of in English work is the eupatheoscope. It is essentially a black-painted hollow copper cylinder 7½ in. in diameter, 22 in. long and mounted on a suitable stand. It contains an electric heater which is supplied with a definite amount of heat. The surface of the cylinder is kept at 75°. The heat losses from the cylinder are recorded in degrees of effective temperature.

A similar instrument called the eupatheostat is used to electrically maintain the comfort conditions required. Fig. 1 is an illustration of the thermostatic device inside the cylinder of this instrument.

It comprises a bimetallic strip, one end of which is attached to a light helical spring by a phosphor-bronze ribbon which serves to actuate a pivoted lever. The lever moves between two stops at each of which it makes electrical contact, and controls the operation of a relay. The temperature of operation, determined by means of a thermo-couple soldered to the cylinder, can be adjusted by a screw which presses upon the strip. By means of a ballast resistance, the 20 watts dissipated inside the cylinder can be maintained within one per cent over a period of several months, despite any variation in the voltage up to 10%.

This instrument is sensitive to surrounding objects, to drafts, and to sunshine, and is really an automaton which keeps a close regulation on the room conditions.

Studies Made in School Buildings

Among the studies which have been made by the Industrial Health Research Board are some in school buildings. Let us turn attention to them first.

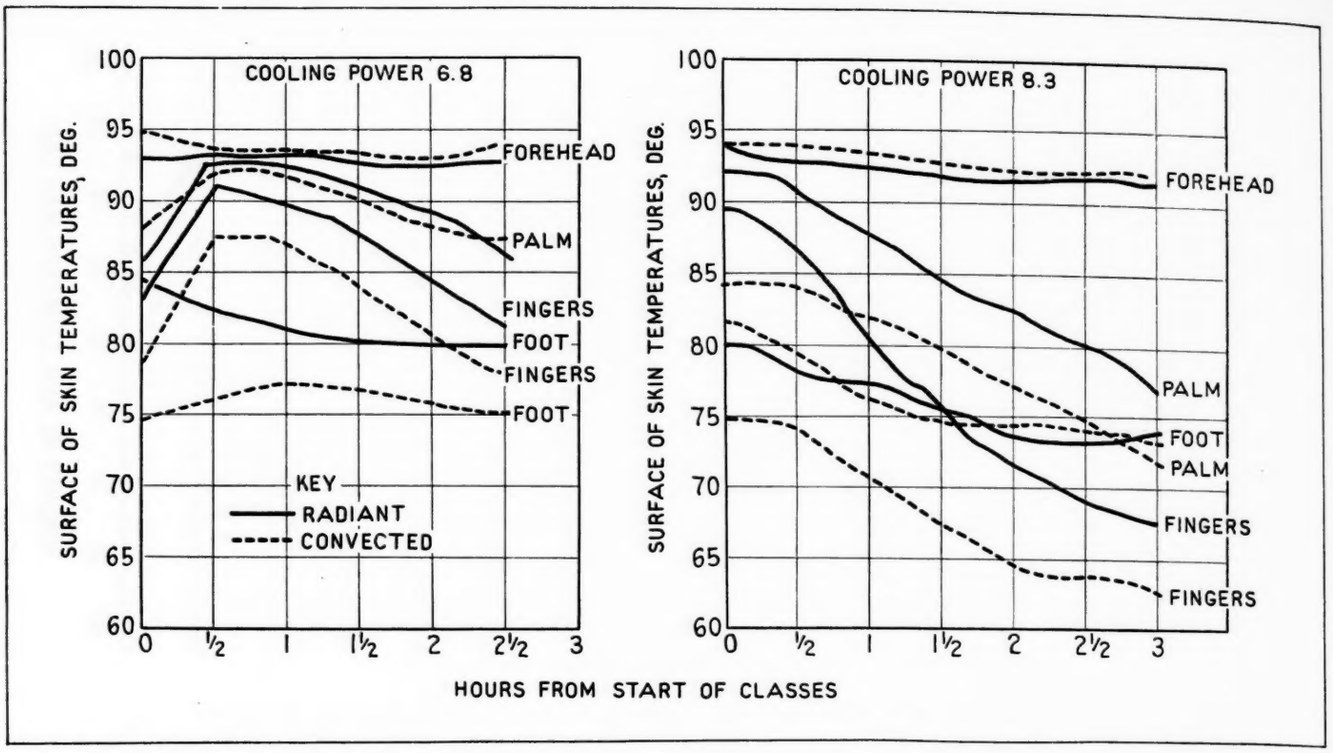


Fig. 5. In the comparison of the two types of systems, as shown on the above graphs, the radiant heated room was a ceiling installation, while the "convected" was really a combination radiant and convected job

These investigations were made largely in a type of school building designed by George H. Widdows, F.R.I.B.A., architect to the Derbyshire County Council. These buildings are of peculiar design and the main features may prove of interest. The rooms are normally 24 feet east to west and 21 ft. 6 in. north and south, with a height of 13½ ft. The north and south sides consist of a single glazed door, together with three pairs of glazed swing doors which can be fastened back against one another. When so fastened the whole classroom is open to the air. Each door is fitted in the upper part with a hopper having gussets fixed at the sides. By opening these hoppers any ventilation area from one square foot to 4½ sq. ft. can be obtained at each hopper. The special feature of the hoppers is that they are so set that the cold air is directed upward and not on the children. Outside each of the north and south sides of the classroom is a broad veranda, on which the children take their lessons in warm weather. The south veranda prevents all but the low-angle winter sunlight from entering the rooms. With no south windows above the veranda it follows that practically no direct sunlight reaches the children. Lighting is accomplished by means of a large north skylight 6 ft. wide running the full length of the room. Heating is done by the underfloor method with hot water pipes embedded in the floor, as described in the July issue. Other schools heated with ceiling panels and rayrads have also been tested.

During the course of its studies, the board obtained data showing the surface temperature of the skin of pupils. Readings of thermopiles were obtained at the head, hands and feet. Incidentally, too, from readings taken, it appears safe to assume that the emissivity of the skin is close to that of lampblack.

The measurements took no notice of humidity and the results contain no reference to it. This is because the humidity in England is so high that, with the lower temperatures used with radiant heating, it is rarely an important factor. In this country, however, this by no means may be true.

The results of the studies are reported in terms of cooling power recorded by a kata-thermometer, the room ventilation being controlled to obtain the desired cooling power.

Fig. 2 shows the relative air temperature at different heights resulting from tests made in classrooms, one of which was heated by an underfloor installation and the other by convection only. Figs. 3 and 4 give the relative skin temperature, Fig. 3 being with a cooling power of 6.8. and Fig. 4 with an 8.3 cooling power. Note that the forehead temperature is lower in the convected heated room in spite of the air temperature being higher. The constancy of the head temperature throughout the tests in spite of the variations in temperature at other parts of the body is also noteworthy. The temperature changes of the feet during the course of the tests are rather marked. The effect on the finger temperatures is also great. The recorded sensations of air temperature are the feelings as described by the investigators using an arbitrary numerical scale.[1]

The investigators' comment in their report on these tests was: "There can be no doubt that at equal cooling powers the air in the floor heated room felt warmer and less in motion than the air in the convected heated room."

[1] EDITOR'S NOTE—The scale used was:

Sensations for Air Temperature		*Sensations for Air Movement*	
Much too warm	(1)	Very stagnant	(1)
Too warm	(2)	Stagnant	(2)
Comfortable	(3)	Medium	(3)
Too cold	(4)	Fresh	(4)
Much too cold	(5)	Very fresh	(5)

Comparative Study in a Ceiling Heated Room and a Convected Heated Room

Another test made by investigators of the board was conducted in rooms, one of which was heated with ceiling radiant heating, and the other by gas fires screened to prevent radiation. Analysis of the results tends to indicate, however, that the object of preventing radiation was not fully accomplished and that the tests were really of a ceiling radiant heated room and one heated by a combination of radiant and convected heat. Fig. 5 gives the results of this test plotted in a fashion similar to those given in Figs. 3 and 4.

Study of a Machine Assembly Operation

Another study of enough interest to be worthy of noting at this time is one made in a room in which a simple operation requiring manual dexterity of the fingers was performed. The operation had to do with the assembly of bicycle chains and was performed in a radiant heated room and in a convectively heated room. The actual operation consisted of picking up studs and inserting them in the holes of the two combinations which had to be connected together by means of links. The links had to be taken from a pile and balanced on the top of the studs in exactly the same way as is done in the genuine operation, but instead of following the operation completely, the links and other pieces were removed and put back on the respective piles.

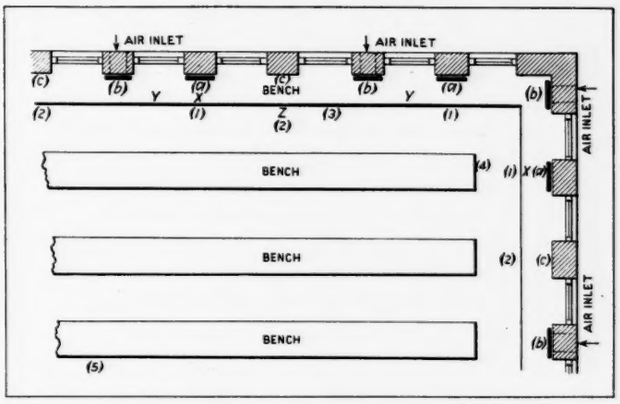


Fig. 6. Floor layout of radiant heated room tested by Industrial Health Research Board

Tests were made in air having a cooling power of 6.8, 8.3 and 10.1. Fig. 8 gives the results of the observations with the series of 9 determinations made at each session treated as a unit containing its own standard.

No specific significance is attached to the temperatures of the fingers but the study is quoted as being of interest as showing that in such operations the temperatures of the hands affect the work output.

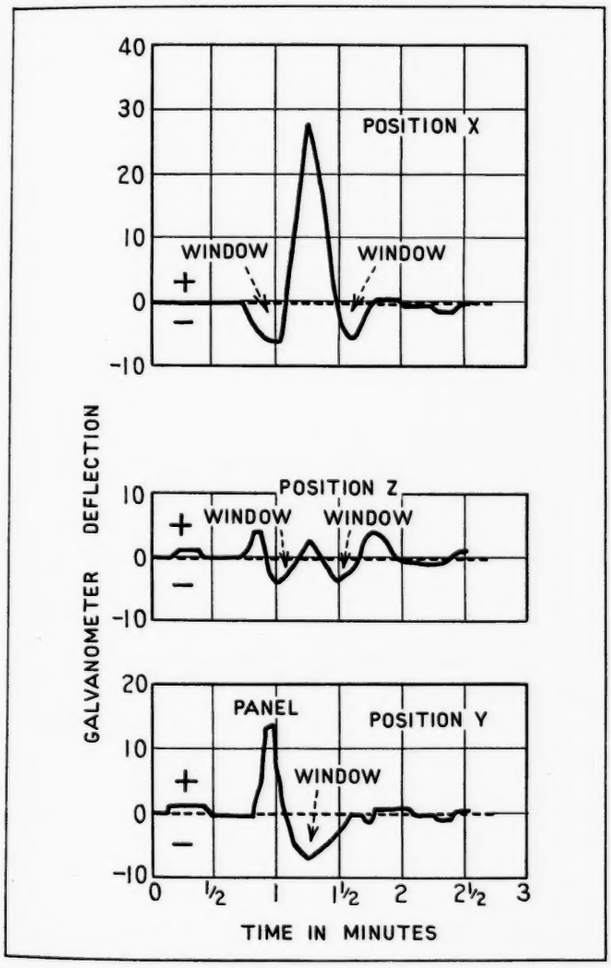


Fig. 7. Thermopile readings of tests made in different positions of the room shown in Fig. 6

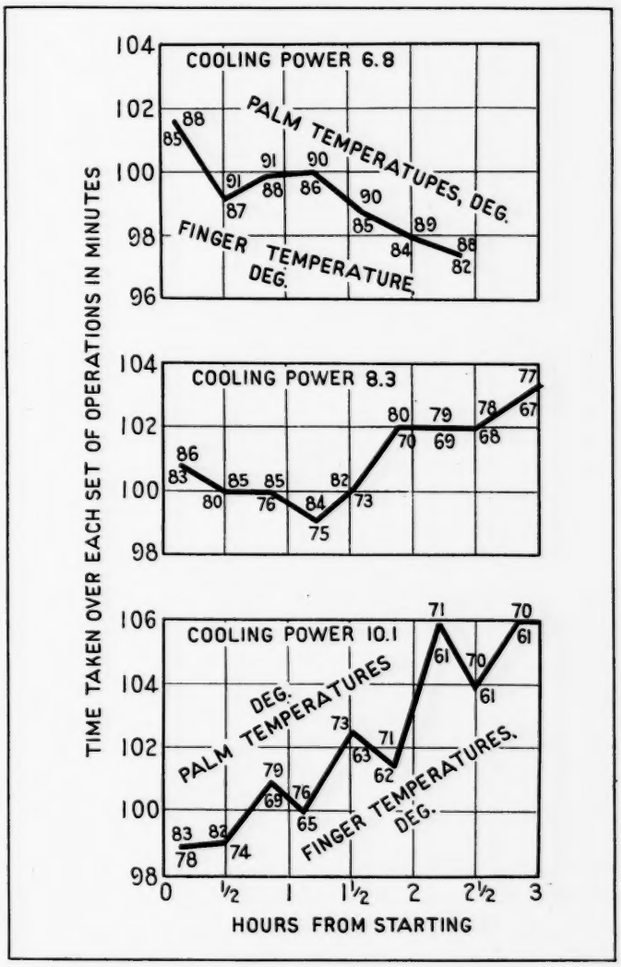


Fig. 8. Results of observations on a machine assembly operation

Study in a Shoe Factory

Results of a study made by investigators of the Industrial Health Research Board in a large shoe factory where radiant heaters are installed in the surface of the side walls illustrates how conditions may satisfy a large majority of people and yet have opposite effects upon others. Most of these investigations were made in a room 273 ft. x 47 ft. x 12 ft. high at the eaves and 21 ft. at the apex. The room accommodated 400 women who were sitting at benches sewing the uppers of shoes by means of electrically driven machines.

Fig. 6 is an approximate plan of the floor layout of the room, showing benches adjacent to the walls at which benches some of the girls work.

The heating panels installed on the pilasters marked (a) are radiant panels; those on pilasters marked (b) are shielded so that air can be brought in from the outside at the bottom and discharged at a level of 8 ft. above the floor; the pilasters marked (c) are plain wall surfaces, and this arrangement is repeated the whole way round the building.

Thermopile readings were taken at the locations marked X, Y and Z and the records are shown graphically in Fig. 7. Point X was 2 ft. from the heating panel where a temperature of 118° was recorded by the thermopile when directed toward the panel, but when the thermopile in the same position was turned toward the window, it indicated a temperature 11° below that of the room (57°). At position Y, which was directly opposite a window, it indicated a negative temperature of 13° below that of the room, when directed on the window.

In order to ascertain the influence of the radiation on the sensation of warmth, the girls were questioned systematically during the times that the kata-thermometer observations were made.

The girls were separated into the following five groups, depending on their working positions in the room: (1) 2 ft. from a warm panel, (2) 2 ft. from a plain wall, (3) 3 ft. from a window, (4) at one end of the inner benches, 6 to 10 ft. from walls and windows, (5) in the middle of the room, 22 ft. from walls or windows.

Altogether 356 expressions of sensations were taken and are tabulated in Table 1, where percentages are given to the nearest whole number. From this it will be noted that 78% gave the mean condition as being comfortable, whereas 3% gave it "much too warm" and 1% gave it as "much too cold."

If the group in position (5), where conditions can vary only slightly, is analyzed, it will be found that while 88% found the condition comfortable, 6% found it "too warm" and another 6% found it "too cold."

TABLE 1

PER CENT OF SENSATIONS EXPERIENCED

	Much too warm	*Too warm*	*Comfortable*	*Too cold*	*Much too cold*
(1) 2 ft. from panel.....	3%	20%	68%	8%	1%
(2) 2 ft from wall or covered panel	9%	9%	69%	13%	0
(3) 3 ft. from window.....	0	7%	82%	9%	2%
(4) 6 ft. to 10 ft. from panel	2%	10%	87%	6%	1%
(5) 22 ft. from panel.....	0	6%	88%	6%	0
Mean	3%	10%	78%	8%	1%

It is worthy of note, that those sitting at position (3), 3 ft. from a window, gave almost identical expressions of comfort as those sitting 22 ft. away.

Investigations have also been made by the same investigators to gather evidence to show the effect of school conditions upon absenteeism. Unfortunately, the results of these studies are not consistent but point toward a maintained temperature of 63 to 64° with radiant heating as being desirable.

Conclusions

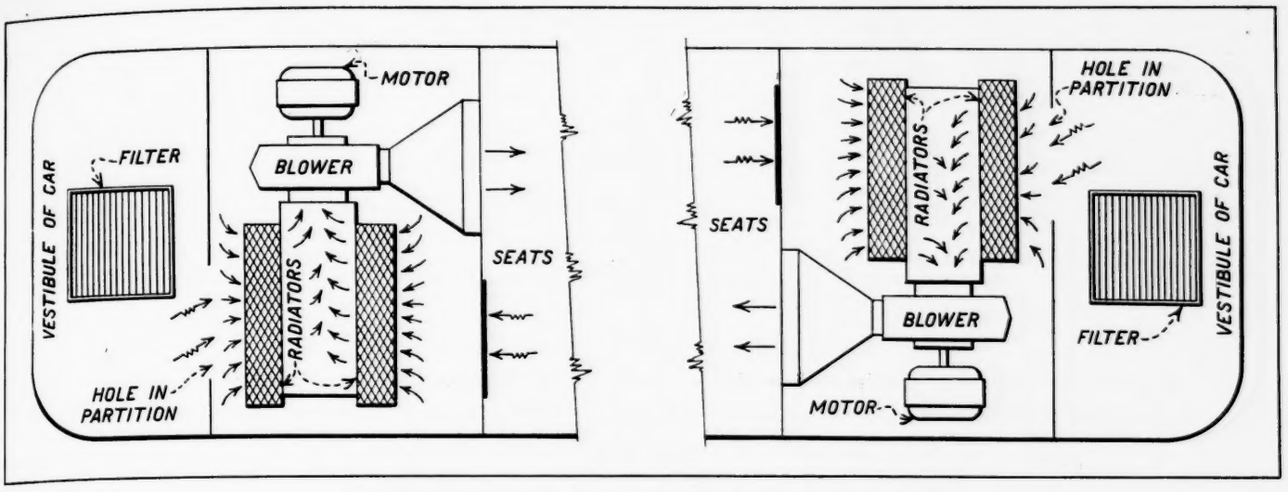
If the development of radiant heating has done nothing else it has served to show very definitely that the actual heat lost from the body under certain set conditions is by no means the only question to be considered by heating engineers. If we are to be successful in our profession we will eventually have to consider the whole matter of comfort for the human body, if it is true that this comfort really depends on the heat dissipation and heat supply.

Through these articles I have tried to give, without going into too many technicalities, a picture of what has been done in England on a commercial scale toward developing an ideal heating method. I do not suggest that either the systems or the methods of application are now ideal, for twenty years have each brought their improvements. Each improvement and each development has made the difficulties of previous years seem worth overcoming. It can be predicted with confidence that future developments will lead to improved methods of providing uniform distribution of thermal radiations in homes and other buildings.

Boston & Maine Cools Railroad Cars with Ice

EARLY in September, the Boston & Maine Railroad placed in successful operation a cooled and conditioned single-sashed passenger railroad coach. The initial run was made between Boston and Troy, N. Y. On September 9 and 10 conditions in the coach were maintained 12° to 14° below the outdoor temperature and 14° to 19° cooler than conditions existing in the other cars on the train.

The method adopted for cooling the coach was a somewhat radical departure from present accepted practices in this field of work. The source of refrigeration is from circulated ice water obtained by spraying water over ice carried in bunkers beneath the coach. It is reported that a uniform ice water temperature is maintained irrespective of the amount of ice in the bunker, and any refrigerating tonnage rate demand is automatically supplied by the ice meltage rate adjusting itself to the load, however it may vary.



Arrangement of air cooling equipment in upper part of car

The method of cooling, dehumidifying and circulating the air in the coach is as follows: Ice water is circulated by means of a small pump beneath the car through lightweight and compact surface coolers. The surfaces are located at both ends of the car and are concealed above a drop ceiling which is below the main roof deck. Above this same drop ceiling on each end are concealed the pressure blowers for air circulation. Air is drawn from one side of the car and through the coolers and discharged at high velocity from a louvered outlet adjacent to and lower than the inlet register. This high velocity outlet air is picked up by the suction inlet directly opposite on the other end of the car. By proper proportioning of the velocities and temperatures involved there is set up on the ceiling two high velocity streams of air, moving in opposite directions.

Cooling of the air at the normal passenger level takes place when the heavier cooled air settles down and the warmed air rises into the overhead mild cyclone. Results free from draughts are reported.

At the ends of each car, floating on the radiator and fan chambers, cloth felt air filters are connected directly to the outdoors. Because of design proportions, a slight static air pressure is maintained in the car. The static pressure finds relief through window and door crevices. This loss of air is replenished by outside air admitting itself to the system through the filters. If a large amount of outside air is desired the operation of existing car exhaust ventilators along the roof allows air to escape from the car and a supply of outside air enters through the filters. The slight static pressure prevents the infiltration of dirt.

The installation is said to be automatic in so far that the use of refined controls are dispensed with. The trainmen need not be especially trained to operate the system. The entire system operates with about two connected horsepower, and less than that amount is consumed or required. Over a period of two days, eleven hours of running in the sun with a range in temperatures outdoors of 65° wet bulb and 77° dry bulb to 75° wet bulb and 94° dry bulb, the average refrigeration tonnage rate required was 4.3 tons, equivalent to the melting of about 350 lb. of ice per hour.

The project was sponsored jointly by railroad officials and the Metropolitan Ice Company of Boston. The engineering details were developed for the ice company by R. B. Engineering Corp., New York.

Ice chamber on Boston & Maine coach, and engineers interested in the installation

Air Conditioning

By WILLIAM HULL STANGLE

Part XIII—Apparatus (Concluded)

By REALTO E. CHERNE

Refrigeration for Conditioning

When summer operation calls for refrigeration effect this may be secured from cold well-water, ice, or refrigeration machines. Refrigeration, particularly as applied to air conditioning, is a lengthy subject in itself. Material will be presented in later articles of this series which will deal with this important item.

Pumps

An additional item of equipment usually necessary is a pump to supply water to the spray nozzles at the proper pressure. For the ordinary installations involving air cooling the amount of water to be handled by the pump is determined by the refrigeration requirements. The head against which the pump must operate may be found by adding the frictional losses in the pipes and connections, the loss through the water cooler (evaporator), and the head required by the sprays to insure the required degree of atomization. A by-pass arrangement at the dehumidifier is generally provided to allow for winter operation, during which time the water is recirculated locally without passing through the water cooler. A centrifugal pump is readily adapted to this seasonal change of load and power costs may be decreased by such operation. Pumps and cold water piping will be discussed at greater length later and are merely mentioned at this point as being necessary.

Spray Water Heaters

Occasionally in comfort work and quite generally in industrial conditioning it is necessary or advisable during winter operation to control the apparatus dewpoint by the use of a water heater which controls the temperature of the spray water. This heater may be either of the closed type, in which a heat interchanger transfers the useful heat of the steam to the spray water, or it may be of the ejector type, in which steam is introduced directly into the spray water. The type of heater selected depends principally upon the character of the job and the steam pressure available. It is evident that an ejector heater would not be advisable for relatively low pressures or relatively high pressures. One manufacturer recommends this type for steam pressures varying from 3 lbs. to 20 lbs. gauge, above or below which the closed type heater is recommended. For control of the ejector heater, one method is to have both a direct-acting and reverse-acting diaphragm valve, the former for dewpoint control and the latter as more or less of a safety device to shut off the steam in event of pump or control-air failure.

A water heater may be used in place of a pre-heater for winter dewpoint control when the ratio of return air to outside air is great enough to prevent any possibility of freezing up of the sprays before the air is heated above the freezing point of water. Total heat calculations such as were used in determining preheater capacities may be used to determine this ratio for any given operating conditions.

The size of spray water heater necessary for any given condition may be computed by determining the amount of heat required to be added to the outside and return air to give the apparatus dewpoint desired. However, in practice, a sizable factor is added to facilitate rapid heating when starting up the equipment on cold mornings. For example, if the outside air required is 10% of the humidifier capacity, it may be well to size the water heater on the basis of 20% outside air to secure better operating characteristics. The amount of steam required in this case, assuming a dehumidifier capacity of 1000 lb. per min., would be:

$$\frac{20\% \times 1000 \text{ lb.} \times (17.6 - 0) \times 60 \text{ min.}}{(1156.9 - 13.07)} = 184 \text{ lb. per hr.}$$

In this equation the 17.6 is the total heat per pound of air at 45° saturated, while the zero in the (17.6—0) represents the total heat of the entering air at 0°. The denominator represents the total heat in a pound of steam at 5 lb. pressure (gauge) from which the heat of the liquid at 45° is subtracted. The size of standard commercial heater required for this heat load and steam condition can be determined from manufacturers' catalogs.

Calculations for closed water heaters are very similar except that the available heat energy of the steam supplied is generally taken as the latent heat of the steam at the pressure of the supply.

Note on the Terms Used

In this discussion the terms *preheater*, *reheater*, and *heater* have been used. To avoid any possibility of confusion it may be well to state that *preheater* is the term used to designate the heating element ahead of

the washer; *reheater* is applied to heating surface in the air passage, after passing the conditioner, or in the recirculated air duct; *heater* refers to the appliance used to heat the spray water.

Frictional Resistances

Fans and drives have been covered in general in previous articles (Parts V and VI, November, 1930, and January, 1931), but the means of selecting the proper fan for a given load was not explained. A fan is selected with regard to the cubic feet of air per minute to be handled and the static pressure against which it must operate. The static pressure may be found by summing up the static losses through the complete system from outside air intake to the outlets or nozzles. This means that the loss due to friction must be determined for each item of apparatus involved. For a system such as has been described in the last few articles, the losses through the outside air intake, filter, preheater, dehumidifier, reheater, ducts, outlets and dampers must be considered. Most of these values may be obtained from manufacturers' catalogs and the remainder may be computed as explained in a previous article (Ducts and Duct Design, HEATING AND VENTILATING, February, 1931).

For a typical example we may assume the following drops in static pressure:

1. A simple outside air inlet, comprised of screen louver and short duct, may have a loss of 0.2 in. of water.
2. A typical oil filter is rated to have a drop of 0.25 in. water at standard velocity.
3. Two rows of preheater are rated by one manufacturer at 0.144 in. water.
4. A commercial dehumidifier, with ordinary velocity being used, may have a loss of about 0.33 in. of water.
5. One row of reheater, using an extended surface tubular heater, has a rated friction drop of 0.174 in. of water.
6. A fair average of duct losses on a simple system may be taken as 0.25 in. of water.
7. The static pressure for a nozzle type outlet may be 0.1 in. of water.

Summing these values we get $0.2+0.25+0.144+0.33+0.174+0.25+0.1 = 1.448$ in. of water, the static pressure against which the fan must operate. With this information at hand the fan for use may be selected.

Power Requirements

The theoretical horsepower required to move a given quantity of air may be easily calculated by either of the following two methods:

1. Volume in cubic feet displaced against pressure per square foot, or
2. Weight against head.

Example: Assume one cubic foot of air per minute to be displaced against one inch water gauge. First convert the one inch water gauge to pounds per square foot as follows: One inch water $= \frac{62.5 \text{ lb.}}{12 \text{ in.}}$ **= 5.196 lb. per sq. ft. Multiplying this by the volume displaced in cubic feet and dividing by 33,000 gives the horsepower, thus:**

$$\frac{5.196 \text{ lb. per sq. ft.} \times 1 \text{ cu. ft.}}{33{,}000} = 0.001574 \text{ hp. to}$$

move one cubic foot of air against one inch water gauge.

The power input to the driving motor is equal to the theoretical horsepower divided by the fan and motor efficiencies.

Part XIV—Mechanical Refrigeration

By R. W. WATERFILL

MECHANICAL refrigeration is the extraction of heat from a body or substance to be cooled and the elevation of that heat to a higher temperature plane so that it may be disposed of through some natural medium, like water or the surrounding outdoor atmosphere. The chemical substances employed as refrigerants are merely convenient physical vehicles for the heat.

Refrigeration Systems

Important systems of mechanical refrigeration employed at present may be classified generally as compression, absorption (Fig. 1) and adsorption. The compression types include positive gas compressors and non-positive compressors. The reciprocating piston and valve machine is representative of the positive type. Another modification is the rotary, eccentric drum in a cylinder, or some form of gear pump. The non-positive compressor which employs kinetic energy, instead of mechanical displacement and clearances, is represented by the centrifugal compressor (Fig. 2) and the vapor ejector (Fig. 3).

The absorption system is based on the ability of some liquids to absorb the vapors of other fluids. The majority of such systems employ water as the absorbing medium for ammonia vapors, though other combinations are entirely possible and occasionally used. Its operation depends largely on a balance of temperatures and, in general, the system is more bulky than the mechanical system.

Closely allied to the absorption system is the adsorption system. This utilizes a solid substance with a large volume of active capillary pores for adsorbing and concentrating the vapors of the refrigerant. Such solid substances include activated charcoal, silica gel and others.

Refrigeration Media

While the great majority of refrigerating systems have employed some working fluid which is liquefied and re-evaporated in successive stages of the operating cycle, it is entirely possible to obtain cooling effect by other media. For example, air was used extensively at one time aboard ship—a use warranted because of its

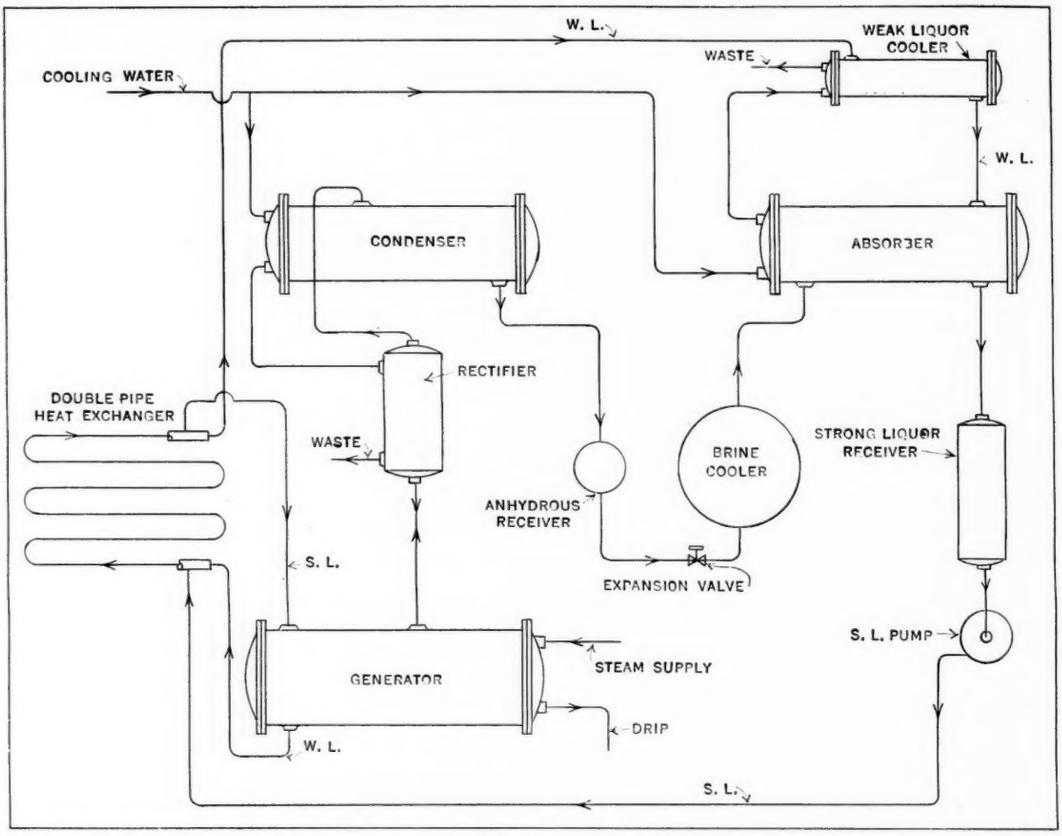


Fig. 1. Schematic drawing of steam-operated absorption refrigerating system

safety from the possibility of leakage of a dangerous chemical refrigerant. This system, however, was cumbersome and inefficient and is now generally supplanted.

Some of the earliest machines (of the absorption type) employed sulphuric acid and water, and later ammonia and water. These were followed by apparatus using the reciprocating piston gas compressor. Various minor modifications of this method were used until recent years.

Some of the first refrigerating media used in gas compressors were ether, sulphur dioxide and ammonia. The latter has been much favored in the United States for use in large compressors of the reciprocating piston type. European countries have favored sulphur dioxide as a general medium.

Within the past few years there have been improvements in the piston type compression machine with multivalves permitting higher speeds. Electric motors contributed to the higher speeds and flexibility, supplanting cumbersome slow speed steam engine-driven compressors. The electric motor also made possible wider use of small sizes which are more nearly automatic in their operation. The domestic size for household refrigerator boxes has been made practical and firmly established itself in this period. In the larger sizes an entirely new system has been developed using a centrifugal compressor for compressing the refrigerating medium. Its use required the development of entirely new refrigerating media.

Still further advances may be expected within a few years, resulting in systems which will make complete

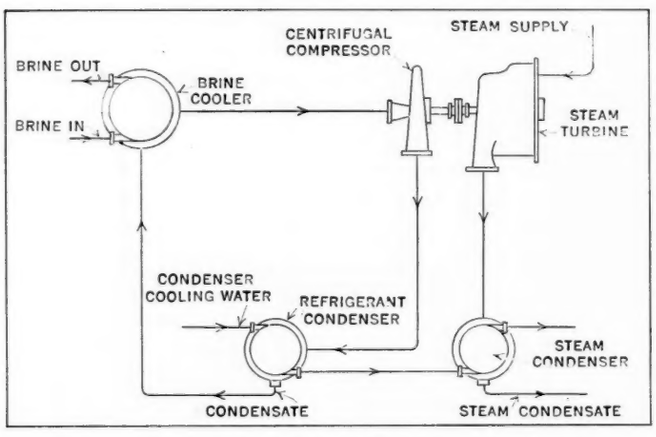


Fig. 2. Diagram of mechanical compression system of refrigeration

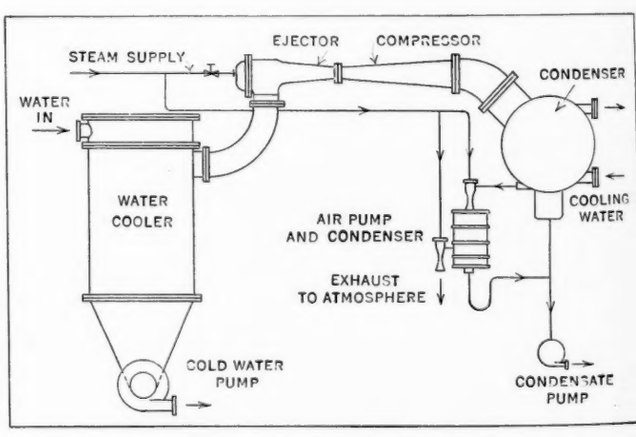


Fig. 3. Steam ejector refrigerating system

TABLE 1

ONE-TON REFRIGERATION, 5° TO 86° F.

Cycle	Weight Lb. Per Min.	Volume Cu. Ft. Per Min.	Initial Pressure at 5° F.§	Final Pressure at 86° F.§	Ratio of Comp.	% Power Loss*			Coefficient of Performance	Horse Power	% Efficiency	Remarks
						Liquid Expansion	Superheat	Total				
Carnot	.....	.....	.....	.....	....	0	0	0	5.74	.8214	100.	
Ammonia	.4214	3.44	34.28 lb.	169.2 lb.	4.93	10.94	7.49	18.43	4.85	.973	84.5	
Propane	1.396	3.35	43.70 lb.	159.0 lb.	3.64	9.45	8.25	17.7	4.88	.9668	85.	
Carbon Dioxide	3.74	.999	334.0 lb.	1039.0 lb.	3.11	97.9	26.55	124.45	2.56	1.843	44.6	
Carbon Dioxide	2.091	.559	334.0 lb.	1039.0 lb.	3.11	33.4	17.35	50.75	3.81	1.238	66.4	
Carbon Dioxide	4.081† 2.625	.702	334.0 lb.	1039.0 lb.	3.11	38.85	18.63	57.48	3.65	1.294	63.6	3 Stage Liquid Cooling Liquid Subcooled to 70° F.
Sulphur Dioxide	1.388	9.24	11.81 lb.	66.60 lb.	5.63	9.75	11.48	21.23	4.735	.995	82.5	
Ethyl Ether	1.555	60.8	3.52 in.	25.05 in.	7.12	18.21	0	18.21	4.86	.971	84.6	
Dichloroethylene	1.768	108.4	1.70 in.	14.0 in.	8.23	10.45	1.27	11.72	5.14	.918	89.4	
‡Carbon Tetrachloride	2.532	307.	.53 in.	5.62 in.	10.58	11.12	1.68	12.8	5.09	.927	88.6	
Trichloroethylene	2.137	513.	.315 in.	3.42 in.	10.84	10.95	1.98	12.93	5.085	.928	88.5	
Water	.1996	1972.	.0569 in.	1.248 in.	21.9	4.62	35.3	39.92	4.1	1.15	71.5	Over Water
Dichloromethane	1.485	74.	2.39 in.	20.48 in.	8.56	10.8	6.6	17.4	4.9	.965	85.3	

*Per cent of Carnot. †Weight in Condenser.

‡Carbon tetrachloride impracticable because too active chemically—dissociates and forms free chlorine.

§ { Pressures below atmospheric stated in inches of Mercury. / Pressures above atmospheric stated in lb. per sq. in.

air conditioning benefits available in the private homes. Railroads are beginning to see in refrigeration with air conditioning a means of improving their passenger service to make travel more attractive, and regaining some of the patronage lost to the automobile.

The refrigerating media which it is possible to use, and which have been used to some extent, include many substances, some of which are: ammonia, sulphur dioxide, carbon dioxide, water, air, methyl chloride, ethyl chloride, propane, butane, ether, ethane, carbon tetrachloride, dielene, trielene, dichloromethane and dichloro-difluoro-methane. Practical considerations at present have reduced those actively employed to ammonia, carbon dioxide and dichloromethane in the larger units, and sulphur dioxide, methyl chloride and dichloro-difluoro-methane in the smaller machines.

Table 1 gives standard ton data of the physical properties of the principal refrigerants.

Temperatures are the criteria of comparison of all condensable refrigerating media. The liquefaction and vaporization pressures are characteristics peculiar to the individual substances themselves. The theoretical cycles and performances can best be determined from temperatures and total heats. A knowledge of the pressures and volumes is of value chiefly in determining the character and construction of the mechanisms employed in the system. For instance, ammonia with moderate pressures and volumes is ideally suited to piston type compressors of large tonnage capacity. It is hardly suited to centrifugal compression because the proportions of volume and pressures would require the construction of disproportionate mechanisms. On the other hand, dichloromethane with very low pressures and large volumes is ideally suited to centrifugal compressors but is altogether impractical for use in a piston type machine.

The Refrigeration Cycle

The principle of the basic thermodynamic cycle employing a liquefiable refrigerating medium is illustrated by the Carnot temperature-entropy diagram (Fig. 4). This is based entirely on temperatures and total heats, the total heat at any point in the cycle being equal to the product of the absolute temperature and entropy of the point. The refrigerating cycle involves the absorption of heat at constant temperature along the

TABLE 2

PHYSICAL PROPERTIES OF REFRIGERANTS

	Ammonia NH_3	Carbon Dioxide CO_2	Sulphur Dioxide SO_2	Methyl Chloride CH_3Cl	Dielene $C_2H_2Cl_2$	Dichloromethane CH_2Cl_2	Dichlorodifluoro methane CF_2Cl_2*	Water
Molecular weight	17	44	64	50.5	96.9	84.9	120.9	18
Boiling point (1 atm.) ° F.	—28°	—108.4	14	—10.7	122	105	—21.5	212
Melting point (1 atm.) ° F.	—107.9	—160.6	—98.9	—143.7	—70	—142	—247.0	32
Critical temperature, ° F.	271.2	87.8	314.8	289.6	470	421	222.7	706.1
Critical pressure, lb. per in.² abs.	1651	1071	1141.5	969.2	800	1490	581.5	322.6
Specific gravity-liquid (Water = 1)	.64	.89	1.43	.95	1.27	1.33	1.4	1.0
Specific gravity-vapor (Air = 1)	.596	1.529	2.264	1.784	3.36	3.0	4.16	.622
Specific heat-vapor C_p	.52	.21	.154	.24	.162	.154	.165	.44
Specific heat-vapor C_v	.40	.16	.123	.20	.142	.128	.147	.328
Ratio C_p/C_v	1.3	1.31	1.25	1.20	1.14	1.20	1.12	1.34
Absolute pressure at 5° F.	34.28 lb.	334 lb.	11.8 lb.	20.9 lb.	1.7 in.	2.39 in.	26.51 lb.	.0569 in.
Absolute pressure at 86° F.	169.2 lb.	1039 lb.	66.6 lb.	95.5	14.0 in.	20.5 in.	107.9 lb.	1.248 in.
Volume-vapor at 5° F., ft.³-lb.	8.15	.267	6.66	4.53	63.	49.9	1.485	9880‡
Latent heat at 5° F., B.t.u. per lb.	565	115.3	170.7	178.5	136.	162.	69.47	1088‡

†CO_2 not liquid at atmospheric pressures. *A.S.R.E. circular No. 12. ‡Estimated over water to maintain same basis as other refrigerant.

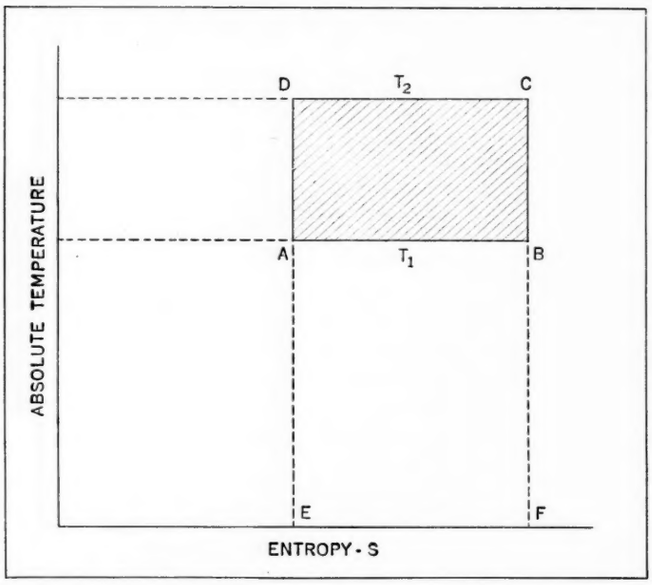


Fig. 4. Temperature entropy diagram of Carnot cycle

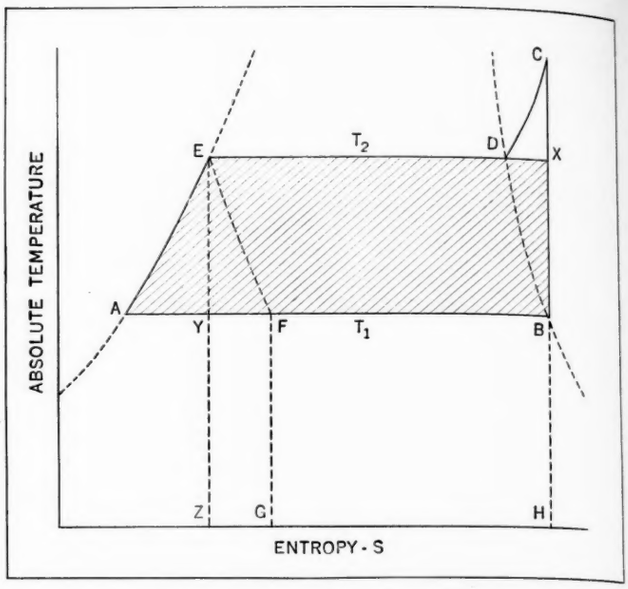


Fig. 5. Variation of practical cycle from theoretical

line AB by evaporation of the refrigerating medium and the elevation from T_1 to T_2 adiabatically along the line BC by compression of the vapors to a higher pressure. The disposal of this heat is effected at the higher constant temperature T_2 along the line CD by condensation of the refrigerant vapors in the condenser. The theoretical medium is then re-expanded at constant entropy along the line DE from the condenser pressure to the lower pressure of the evaporator or brine cooler.

The refrigerating work done is represented by the area under the line AB. The work done in elevating this heat from T_1 to T_2 is represented by the area ABCDA. The total heat discharged to the condenser includes both of the above areas and is that below the line CD.

In this simple cycle the relative heat capacities are proportional to temperatures. In other words, the ratio of the work done to the refrigerating effect obtainable equals

$$\frac{T_2 - T_1}{T_1} \text{ (absolute temperatures)}$$

The reciprocal of this expression is known as the coefficient of performance and is not an expression of efficiency. The fact that the refrigerating effect expressed in B.t.u. usually exceeds the mechanical work of executing the cycle frequently gives the impression that an efficiency higher than 100% has been obtained. Such, however, cannot be the case and is merely an expression of the amount of work required to move a given quantity of heat from one position to another at a higher temperature.

Liquefiable refrigerating media employed in practice cannot function in a cycle as efficient as the theoretical Carnot. Fig. 5 shows the general deviation of the practical fluids from the theoretical. This practical cycle involves losses in both compression and in re-expansion of the fluid even when employing a mechanism of 100% efficiency. Most liquefiable fluids used in practice have an efficiency of approximately 85% to 90% compared with the Carnot cycle. Fluids which are not liquefiable or which have critical temperatures within or close to the operating zone, like carbon dioxide, have correspondingly lower efficiencies. Table 2 illustrates the theoretical performance of some of the principal fluids and their comparison with the Carnot cycle.

In actual practice the efficiency of the compression mechanism must be allowed for in determining the power requirements. This practical efficiency varies somewhat with the size of the unit and with the refinements which may be added to minimize some of the normal losses. It is infrequent however, that a complexity of refinements is warranted, except in larger installations, for the small gains obtainable. With average standard stock equipment a reasonably safe practice is to add 50% to the theoretical adiabatic horsepower of the fluid to determine the actual brake horsepower requirement. This includes allowance for volumetric efficiency, mechanical efficiency, and a reasonable deviation of practical conditions from laboratory conditions.

The overall efficiency of the mechanical compressor is the resultant of the volumetric efficiency and the thermodynamic efficiency. The volumetric efficiency is the ratio of the actual displacement to the total mechanical displacement of the piston. Its losses include valve resistance, leakage, and others. The thermodynamic efficiency is the result of the temperature rise of the vapors during compression, thus requiring the actual compression of a larger volume than originally drawn into the cylinder at the temperature of the back pressure. Other losses which reduce the overall efficiency of the system are pressure drop due to resistance in the lines to and from the compressor, in super-heating of the gas entering, and in deviation of the actual back pressure from that required to produce the desired results.

This latter loss is particularly important in systems operating at partial load where variations of capacity by speed regulation or other means are not available to take full advantage of the reduced displacement requirements.

Operating Data for Gas Cooled Residences‡

No single research activity has created more general interest during the past year than that of house cooling. You are all probably aware that during the year three experimental installations were made in three widely separated sections of the country. Two of these installations were in operation long enough to secure valuable information on this important subject.

The research committee, after a thorough investigation, decided that a dehumidifying cooling system using silica gel was the most promising method which could employ gas fuel as the principal operating medium. Consequently, two humidifying units were ordered for installation—one in a home in Pelham, and the other in Chicago, Ill. These two silica gel units supply slightly cooled dehumidified air in the space which is to be conditioned. A circulating fan maintains the movement of air through a circuit which includes the conditioned space, silica gel unit, and the supply and return ducts. A portion of the moisture-laden air returning from the conditioned space is by-passed through a silica gel dehumidifier and rejoins the main air stream, thus providing a mixture whose moisture content is lower than that of the returned air. The mixture is then propelled through an indirect water cooler which reduces its temperature slightly, and is then distributed by the duct system to the space to be conditioned. A duct equipped with a slide shutter makes it possible to draw in as much or as little outside air as may be found desirable.

The Chicago and Pelham installations, although with identical equipment, showed somewhat different operating characteristics. These differences were brought about by the different rate of air infiltration in the two houses, as well as difference in temperature and humidity. It would appear from observations made during the past summer that the Chicago climate shows a greater need for dehumidification than that in Pelham. This is manifested by the following record of operating time.

The Pelham system was in operation for seventy-nine days, this installation being ready for operation as early as June 25. During this entire seventy-nine-day period 325 hr. of operation were recorded. The Chicago system was not put into operation until pretty near a month later, having only forty-eight days of operation, and during this period was in use 338 hr. One factor, however, had a material effect in reducing the need for air conditioning in the Pelham installation during the latter part of the summer. Approximately August 1, the Pelham house was completely insulated and thereafter there were only four days where the temperature and humidity in the house were such that operation was necessary. In addition to that, local conditions such as shade and exposure have their effect. Computed on a theoretical basis from the period of May 15 to September 15 it would appear that the Pelham system would require 500 hr. of operation and the Chicago system 850 hr. of operation. Expressed in percentage this would be: Pelham 16.7% of the time; Chicago 28.8%. Continuous operation for more than eighteen hours occurred five times at Pelham and four times at Chicago. High night temperatures accompanied by high moisture condition of the outside air causing extreme humidities necessitated these long periods of operation.

Both houses are equipped with warm-air heating plants for winter operation. The conditioning systems used the same ducts to distribute air, and though the duct systems were not specifically designed for air conditioning they functioned well enough to maintain uniform temperatures and humidities in the conditioned space.

Both the Chicago and Pelham systems were manually operated, the system only being in operation when the occupants felt that greater comfort was desirable. It would appear that if automatic control is attempted, all doors and windows would have to remain constantly closed, as under these circumstances rapid changes of outside conditions from comfortable to uncomfortable would not be immediately felt inside and the system would, therefore, not operate unnecessarily. It is also believed that there would be a difficulty of habituating people to keeping all doors and windows closed and this would complicate the problem of automatic control.

The cost of operation per hour of the respective systems after final adjustments and changes have been made appears below:

PELHAM SYSTEM, 8-28-31

Gas	145.5 cu. ft. at $ .60 per M	—$ .087
Water	36.5 cu. ft. at 4.00 per M	— .146
Power	1.5 kw. at .04 per kw. hr.	— .060
Total hourly cost		$ .293

CHICAGO SYSTEM, 9-10-31

Gas	118.8 cu. ft. at $ .78 per M	—$ .092
Water	53.7 cu. ft. at .60 per M	— .021
Power	2.39 kw. at .037 per kw. hr.	— .088
Total hourly cost		$ .212

The gas consumption is higher and the power consumption lower in Pelham because the Pelham system treated 25% more air and circulated 80% less, therefore requiring more gas for reactivation and less power for the circulating fan. The Pelham system's water consumption was reduced to a rate only sufficient to keep the house temperature from climbing. Cheap water in Chicago made this refined regulation relatively unnecessary. As an illustration of how existing unit costs of power, gas, and water affect the cost of

‡ Abstracted from Industrial Gas Research and Its Relation to Gas Sales, presented before the Industrial Gas Section, thirteenth annual convention, American Gas Association, October 12-16, by N. T. Sellman, director of sales and utilization, Consolidated Gas Company of New York.

operation, the Pelham unit costs are applied to the Chicago consumptions and vice versa. A comparison of total cost appears below:

PELHAM SYSTEM

Gas	145.5 cu. ft. at $ .78 per M	—$ .114
Water	36.5 cu. ft. at .60 per M	— .021
Power	1.5 kw. at .37 per kw. hr.	— .055
Total hourly cost		$ .190

CHICAGO SYSTEM

Gas	118.8 cu. ft. at $ .60 per M	—$ .071
Water	52.7 cu. ft. at 4.00 per M	— .211
Power	2.39 kw. at .04 per kw. hr.	— .095
Total hourly cost		$ .377

You will note that by merely changing the relative rates but maintaining the units of consumption the Pelham system is reduced from 29.3 cents per hr. to 19.0 cents per hr., and the Chicago system raised from 21.2 cents per hr. to 37.7 cents per hr. Even with Chicago's low water rates it appears most important that water consumption must be either materially reduced or preferably eliminated.

In my opinion the next step is to develop an air cooled silica gel dehumidifying unit coupled with an air cooled silica gel water vapor refrigerating unit for the purpose of lowering the temperature of the circulating air. This system would be a good load builder for both gas and electricity and be entirely void of the usual restrictions to which large refrigerating systems are subjected. The water used in the refrigerating portion of the system would be of little consequence.

A third installation of different design was made in Dallas, Texas, but was not completed until the end of the past summer so no operating information is available. A brief description of the Dallas system is of interest because it embodies a different application of the silica gel absorption system. In Dallas where relative humidity of the outside atmosphere is consistently low and temperature high, the silica gel system supplied air which had been cooled only. The air is circulated as in the other system, the returning warm air, however, passes through an indirect water vapor cooler and is distributed to the conditioned space. The silica gel unit in this case employs its absorbent properties for producing a water vapor refrigerating cycle. The water from a condenser is expanded to vapor in the coils of the water vapor cooler. The latent heat of evaporation is supplied from the air passing around the coils. The vapor passes from the cooler to the gel unit where it is absorbed, the action of absorption producing a partial vacuum which induces the motion of the water vapor. The absorbed vapor is revaporized by the heat of steam in the coils imbedded in the gel and proceeds to a condenser, the condensation causing a vacuum which further induces the motion of the water vapor. From the condenser water travels to the expanding coils. Steam is supplied by a gas-fired steam boiler. The condensing water is cooled in an evaporative cooler and reused.

Referring again to furthering the development in this system of air conditioning the next step would be to construct a system which would be a combination of what was installed in the northern climates and that installed in Dallas with the addition that all cooling and condensing be accomplished by circulating air.

Cost Data for Residence Cooling and Heating

HERE are some interesting figures of costs, as of 1931, for a Chicago house. The warm-air furnace plant is of the elaborately designed duct type. The hot water plant uses unit heater-coolers in the principal rooms, each having a built-in electric fan. The warm-air furnace plant has an air washer with an electric spray pump for heat transfer from the refrigerated water. The hot water plant uses forced circulation cold water through the pipes and radiators. The warm-air plant has only the unobtrusive registers in the rooms, while the hot water plant has enclosed cabinet radiators, which occupy valuable space.

When I commenced these comparative tabulations on October 2, based on accumulated data, I had no idea how they would emerge. I am surprised myself!—*Samuel R. Lewis in an address delivered before the Commercial Section, American Gas Association, Thirteenth Annual Convention, October* 12-16.

	Mechanical Warm Air	Forced Hot and Cold Water
Investment Cost (Actual Bids)	$3000.00	$4000.00
Interest and depreciation 4.3% on 15 year basis	129.00	172.00
Gas for heating 560 B.t.u. per cu. ft. at 75% efficiency at 85c per 1000 cu. ft.	826.00	826.00
Electricity for main fan 2520 hrs. at 565 W., at 5c kw.	71.00	
Electricity for unit fans 2520 hrs. 380 W. at 5c kw.		48.00
Electricity for pump 120 W., 2520 hrs.		15.00
Annual Cost of Heating	$1026.00	$1061.00
Investment Cost for Cooling—		
Washer and refrigerating plant	$3400.00	
Water cooling plant		$2225.00
Interest and depreciation 4.3% on 15 year basis	146.00	95.50
Electricity for compressor 4.56T 600 hr. 1.2 kw. at 5c k.w.	164.00	164.00
Electricity for pumping water	9.00	6.00
Water for condenser	29.70	29.70
Operate the ventilating fan	18.00	
Operate the unit cooler fans		12.00
Annual Cost of Cooling	$366.70	$307.20
Cost per season for year-round comfort	$1392.70	$1368.20

Abstracts . . .

Reviews and Summaries of . . . . Current Papers, Books and Pamphlets

Welded Pipe and Fittings in Heating Installations

By Fred J. Maeurer

A paper presented before the American Welding Society, September, 1931. Approximately 3500 words, 18 photographs and diagrams.

This paper is a statement of present conditions and practices in the use of oxy-acetylene welding for heating piping.

The author sees definite evidence of the increasing use of welding for such piping, and of its general acceptance, in the increase in the number of welded fittings coming on the market. He also feels that the use of thin wall pipe for heating is inevitable and will appear within the next few years. The increasing availability of good welders as a result of vocational school courses, and the fact that steamfitters have accepted the necessity for becoming pipe welders, are also looked upon as evidence that the use of welding in heating installations can be expected to increase.

The author feels that even now welding can be considered the standard practice and gives as a reason for the change in practice that it is better. In addition he states that efficiency, economy and weight saving are important reasons for the change in practice.

The efficiency is stated to be increased due to decreased frictional losses which result from the use of welded fittings and the increased strength at the joint.

Economy effects are listed as (1) saving in pipe cost because of fewer joints, (2) saving in insulation cost, (3) decreased maintenance charges, (4) absence of scrap material, (5) less cost of moving the erecting equipment, (6) use of stock pipe lengths at lower cost, (7) anticipated saving because of expected developments of thin-walled pipe.

Weight saving is illustrated by a photograph and by an example quoted in which the saving was seven tons.

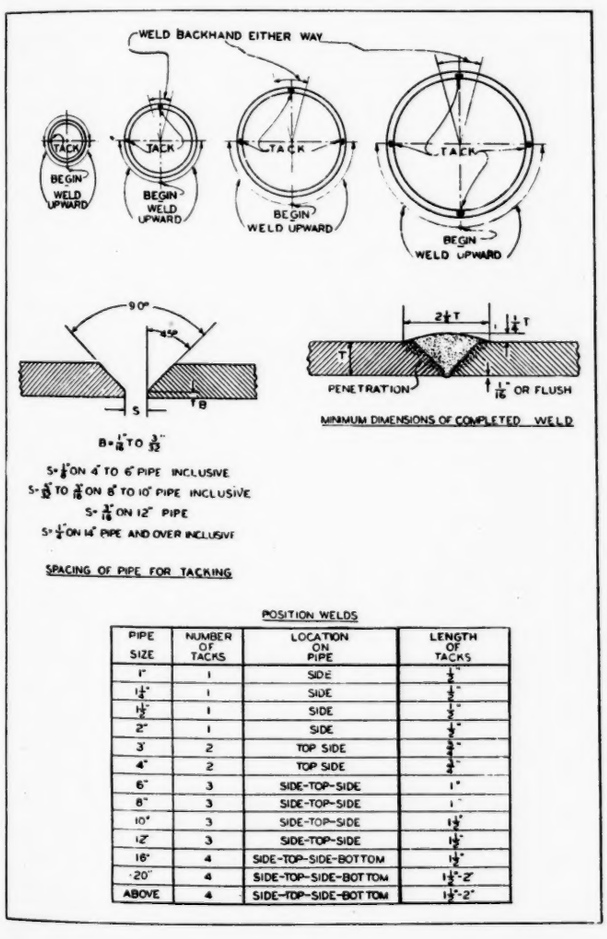
Discussion of the use of field fabricated and manufactured welding fittings mentions the ease with which field fabrication may be accomplished. Among the advantages accompanying the use of welding is mentioned the item of increased ability to install the pipe in cramped locations.

Under the heading "Welded Piping in the Home" the following occurs:

"A rather general impression in former times was that, in a welded heating installation, it was only economical to weld pipe above 2 in. in diameter and that all pipe below this size should be joined together by the old screw-fitted method. This is a fallacy that has been exploded. There are just as many economies to be had in the welding of the smaller size pipe as there are in the larger size pipe.

"The welding of pipe in the heating plants of bungalows and one- and two-family houses is being done at present to a greater extent than is commonly known, and this type of work has proved profitable to the contractor. In welding a small house-heating installation, the same standards of beveling, spacing and tacking should be carried out as with pipe of larger sizes."

The figure reprinted herewith is of interest as giving what the author considers good practice in spacing, tacking and welding.



POSITION WELDS

PIPE SIZE	NUMBER OF TACKS	LOCATION ON PIPE	LENGTH OF TACKS
1"	1	SIDE	1/2"
1 1/4"	1	SIDE	1/2"
1 1/2"	1	SIDE	1/2"
2"	1	SIDE	1/2"
3"	2	TOP SIDE	1/2"
4"	2	TOP SIDE	1/2"
6"	3	SIDE-TOP-SIDE	1"
8"	3	SIDE-TOP-SIDE	1"
10"	3	SIDE-TOP-SIDE	1 1/2"
12"	3	SIDE-TOP-SIDE	1 1/2"
16"	4	SIDE-TOP-SIDE-BOTTOM	1 1/2"
20"	4	SIDE-TOP-SIDE-BOTTOM	1 1/2"-2"
ABOVE	4	SIDE-TOP-SIDE-BOTTOM	1 1/2"-2"

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Friction Heads in One Inch Standard Cast Iron Tees

By F. E. Giesecke and W. H. Badgett

A.S.H.V.E. paper, Swampscott meeting, June, 1931. About 2500 words, two photos and two line drawings illustrating testing apparatus, two graphs showing results.

Results of a cooperative research project between the society and the Texas A. and M. College. A one-inch tee was set up in such a way that 70° water could

be circulated through it with any desired part of the water either passing through direct or through the side opening of the tee. The pressure heads at various points were measured and the friction heads through the tee were computed from the resulting data. The friction head was found to vary sharply with the percentage of water passing through the side opening. A test used for checking the accuracy of the data is also described.

The authors conclude that the variations are of a magnitude which makes them important in the design of piping installations and particularly when applied to hot water heating systems in which slight differences in available heads may produce serious changes in the operation of the heating system.

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Experiments to Determine Heating Effect Factor

By R. N. Trane and C. J. Scanlan

A.S.H.V.E. paper, Swampscott meeting, June, 1931. About 3000 words, 5 photos and two line drawings illustrating the test apparatus, one table and 1 graph showing results.

The authors state that one purpose of the study was to determine why convection heaters require less heat input to maintain the same air temperature within a room than exposed cast iron radiators when the room is exposed to identical cooling conditions in both cases. Also, "the primary object was properly to evaluate the B.t.u. input to a convection heater as compared with that of the various exposed cast iron radiators."

The paper describes and illustrates a test room constructed for the purpose of the tests. Features of the room were the use of light sheet metal walls over the outside of which cooled water could be sprayed, and the use of thermal couples for temperature measurement.

After determining the room characteristics an operating procedure was fixed upon. A breathing line temperature of 72°F. was selected and was maintained during the tests.

The sizes of the heating surfaces were adjusted as necessary to maintain this temperature when the wall surface temperatures were changed. Tests were made with wall surface temperatures of 54°, 58°, 62° and 66°, and with a definite cooling effect in each test. The wall surface temperatures were selected as being those corresponding to outside air temperatures of from —20° to +30°. The results of tests made on three cast iron direct radiators and four convection type heaters are included in tabular form.

The interpretation put on this data by the authors is interesting and unique. They reason as follows: "Because of the fact that equilibrium was maintained during all of the tests, it follows that the heat input to the cold room equals the heat loss. Therefore, inasmuch as the cold surface remained the same in all cases, not only in area but in temperature, and the inner air temperatures remained the same, the only factor of the room that could change was the coefficient of transmission of the wall (U). With a wall surface temperature of 58°F, an exposed cast iron radiator required an input of 3,440 B.t.u. per hr. to maintain a breathing line temperature of 72°. Therefore:

U_{ci} = Over all coefficient of heat transmission of wall for cast iron radiator.

$$= \frac{3440}{166 \times (71 - 58)} = 1.59$$ B.t.u. per hr. per sq. ft. per degree difference between the wall temperature and the average room temperature.

"For a similar wall surface temperature, the convection heater required an input of 2400 B.t.u. per hr. Therefore:

U_c = Overall coefficient of heat transmission for convection heater

$$= \frac{2400}{166 \times (71 - 58)} = 1.11$$ B.t.u. per hr. per sq. ft. per degree difference between the wall temperature and the average room temperature.

"By means of these coefficients, the heat input required can accurately be predetermined. The *heating effect* is therefore equal to

$$\frac{U_c}{U_{ci}} \frac{1.11}{1.59} = 0.7$$

"A comparison of floor line and breathing line differences, or floor line and ceiling differences, for the exposed cast iron radiator and the convection heater tested cannot possibly account for this difference in heat input required to maintain the cold room at 72°.

"The apparent reason for this reduction in heat input required by the convection heater compared with that of the exposed cast iron radiator is that in one case the heat emitted from the exposed cast iron radiator is made up of convected heat and radiant energy, while in the other the heat emission is almost purely convected heat. Inasmuch as convected heat only is capable of raising the air temperature, it follows that in the case of the particular room tested the percentage of radiant energy emitted by the exposed cast iron radiator was 30% as compared to the convection heater tested. No two convection heaters of different designs will have the same *heating effect* coefficient."

After quoting the results found by other investigators and using an example to show how they would apply the heating effect coefficient, the authors present the following conclusions:

1. That the heat loss from any given room or building is dependent upon the source of heat supply.
2. That *heating effect* measures the change of the overall coefficient of heat transmission for a wall under the influence of different sources of heat.
3. That the *heating effect* coefficient applies only to wall and glass loss and not to infiltration loss.
4. That convection heaters should be rated in B.t.u. output at the outlet grille or opening.

As an addendum the paper presents the results of a test made using a plain cast iron section painted with gray lead paint, and a similar one when nickel-plated. From the results of this test the authors conclude that "the difference in heat input required by a convection

heater (nickel-plated, cast iron or non-ferrous) as compared to a cast iron radiator to heat a room to equal standards of perfection is due to the elimination of radiant energy emission in the case of the convection heater."

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Humidification for Residences

By Alonzo P. Kratz

Bulletin No. 230, Engineering Experiment Station, University of Illinois, 28 pages, 6 in. x 9 in., illustrated. Copies may be secured by addressing the Station at Urbana, Ill. Price twenty cents.

A short review of the principles of the relation between comfort in air and relative humidity, and the presentation of test data secured at the experiment station on the subject of residence humidification. Some of the results of these studies have been published previously and other parts of the bulletin are apparently new. Methods of humidifying using furnace pans and radiator pans have been included.

Based on the assumption that humidification is necessary to replace the moisture carried away by the outfiltering air, the requirement is calculated at 11.6 gal. per 24 hr. per 10,000 cu. ft. of space with one air change per hour and with zero outside temperature and 69° and 40% inside. From this, the requirement varies to nothing on certain days. On the same assumption the author points out that the requirement depends greatly on the weather-tightness of the building construction, and especially on the tightness of window openings.

Curves are included showing the results obtained during the studies. One set shows the relative humidities found inside and the quantities of water evaporated with several types of furnace pan humidifiers. Another set shows the results obtained with radiator pans.

As a result of the studies the author concludes that none of the furnace pans tested proved adequate to evaporate enough water to maintain 40% relative humidity in the research residence except in only moderately cold weather, and that none of the water pans tested in radiator shields would prove adequate to maintain this humidity in a residence similar to the research residence in outdoor temperature approximating zero.

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Changes in Ionic Content of Air in Occupied Rooms Ventilated by Natural and by Mechanical Means

By C. P. Yaglou, L. Claribel Benjamin, and Sarah P. Choate

An A.S.H.V.E. paper resulting from research conducted at the Harvard School of Public Health in cooperation with the research laboratory of the society. About 3000 words, 4 illustrations, 1 table.

After discussing briefly the current ideas of the nature and occurrence of atmospheric ionization, the authors describe the modified form of the Ebert apparatus used by them in measuring the intensity of ionization. They state that their instrument was intended to measure that group of ions which they had found to be sensitive to weather changes and to changes in the general indoor atmosphere produced by respiratory and metabolic processes, and by indoor activities.

During the course of daily readings of ionic content of indoor and outdoor air they have noted, among other things, that there are great diurnal and seasonal variations in the ionic content of the atmosphere, that the content is higher in summer than in winter, that it is much higher on clear days than on rainy or foggy or grey days, and that as a general rule it is higher in the day time than at night.

Three series of experiments were conducted.

In the first of these while seven people were seated comfortably in an air-tight steel chamber and allowed to smoke, readings of ionic content were taken both before they entered and continuously while they were in the tank. Under these circumstances the ionic content of air in the chamber was found to fall rapidly while wet and dry bulb temperatures rose moderately.

In another series of experiments, readings were taken in classrooms which were considered representative of such rooms when ventilated by window-gravity methods. Results of one such study are shown in which the ionic content of the air fell rapidly soon after the crowd assembled and remained low throughout the period of occupancy in spite of the room being well ventilated. The ionic content of the air in the room did not rise to its initial value until an hour after the crowd left.

In a third series of tests, twenty-four persons were seated in an air conditioned chamber during a warm day. The plant used made it possible to cool the air somewhat and to measure the quantity of outside air supplied per person per minute to maintain normal ionic content. During the course of these tests it was noted that a ventilation rate as high as 160 c.f.m. per person was barely sufficient to maintain normal ionic content, while the ionic content with 30 c.f.m. was but slightly higher than with no ventilation.

The authors conclude that artificial means must be resorted to to bring about ionization if such ionization is found desirable. Some experiments were conducted during which artificial ionization was practiced and the authors conclude that it is fairly practicable to control the ionic content up to a maximum of 10,000 ions per cubic centimeter without producing a perceptible quantity of ozone. Additional work on the subject is to be reported later.

Additional studies were made in the air conditioned chamber to learn something about the changes in ionic content of the air as influenced by air conditioning processes. It was found that passing the air through a fairly long metal duct resulted in a small loss of ionic content. Passing it over a heating unit increased the ionic content, and passing it over a cooling unit decreased the content. The use of a water spray for humidification or dehumidification resulted in a loss of all small ions but produced a large number of large negative ions.

Simple recirculation of the air without any air conditioning resulted in a reduction of the ionic content.

Your Everyday Problems

Mr. Hanburger will be glad to answer your problems relating to installation and operation of heating and ventilating systems, and wherever possible will give the reasons for his suggestions. Letters will be answered direct to the inquirer and in some cases published anonymously. If sketches are included they should be clearly drawn. Write Mr. Hanburger, HEATING AND VENTILATING, 148 Lafayette Street, New York.

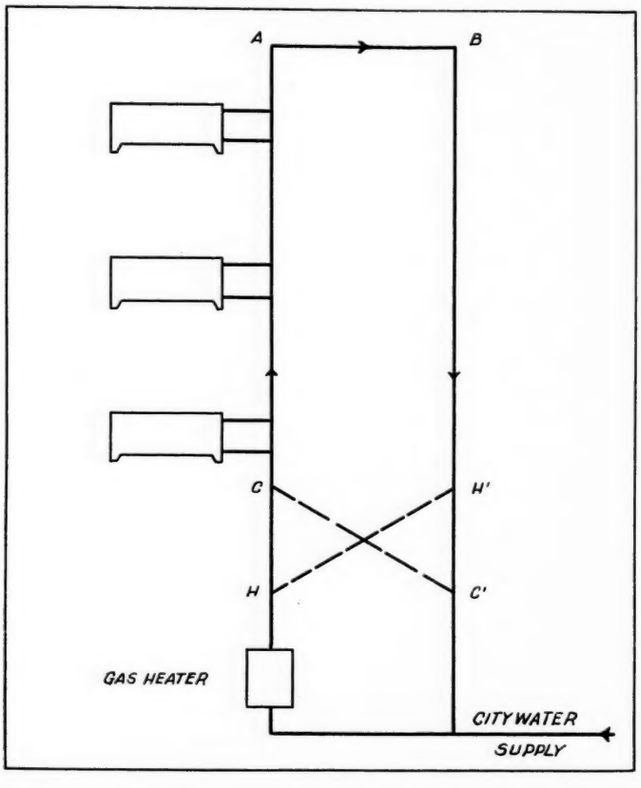
Conducted by FRED W. HANBURGER

QUESTION 20. I am enclosing a sketch of a closed hot water heating system which was installed last Spring and gave poor results. The water is heated by an ordinary gas heater such as is used for domestic hot water heating and the expansion of the water is taken care of in the city supply mains.

The entire system consists of three units, one of which is shown in the sketch below. Regardless of what we do the radiators will not warm up. Is it possible that I have not connected the radiators correctly?

M. M.

ANSWER. You have really violated the fundamental principle of hot water heating by placing the radiators on the rising column. All the power creating circulation depends on the difference in temperature and, consequently, the difference in density of the water in the flow and return risers. The hotter the water in the flow riser and the colder in the return riser, the better will be the circulation. In your hook-up, each radiator tends to cool the rising water and retard circulation.



Instead of changing each radiator connection, you can save much labor by breaking the connections in the cellar and making the connections shown by the dotted lines, cutting the sections of pipe CH and C′ H′ altogether. You will then have a continuous hot water flow from the heater through H, H′ and B and feeding the radiators on the return from A to C to C′ and to the heater. With the original hook-up you have very sluggish circulation. It is presumed that you have an air vent somewhere on the section AB. Any air collecting here would also tend to slow up the circulation. Another suggestion I would make is that with three such units in the building it would be well to put them all on the same water supply line and install a pressure regulating and a pressure relief valve between the heating units and the domestic water supply lines. This will avoid hot water being forced into the toilets and cold water faucets.

QUESTION 21. I have installed a hot water heating system designed along the methods you have advanced in serial in HEATING AND VENTILATING *and the results are excellent, except in the garage where I have used pipe coils. Is it possible that the coils are causing the trouble?*

A. Del L.

ANSWER. If the coils are assembled with return bends there is no doubt that they are causing all the trouble. So much friction is caused in the pipe and the many return elbows that it is best never to use them in hot water heating. If you must have pipe coil radiators, they should be assembled with the aid of manifold headers. The latter are also far more desirable for steam heating systems. The coil with return bends is often noisy. It is sometimes called the trombone coil, and this leads one to believe that its name is well earned.

QUESTION 22. I have observed that publications describe the heating and ventilating equipment in new and unusual buildings but never seem to mention where difficulties were encountered, where parts of the system did not function properly and what changes were made for correction. I can recall several buildings in our section of the country of which I read descriptions of the finished equipment and later through rumor learned of mistakes that had been made in design. Would it not have been more educational to have discussed these?

In medical journals the unusual cases are often discussed; how some cases do not respond to the standard treatment; how and why a wrong diagnosis was made, etc. Again, doctors call in others for consultation in such cases where an engineer will fight his battle alone. Are we, as engineers, ashamed of making or having made errors?

ANSWER. As to the matter of one engineer consulting another, I feel that it is often freely and frankly done, although the one consulted may not visit the "patient," and behind this there is a little hidden thought which you possibly tried to reach in your question and which must be rather tactfully expressed so as not to raise the wrong impression. Analyzing my own thoughts and discussing it with others it might be said that we all feel free to consult with one another on complicated conditions, but at the same time there is a proper aversion to the criticism of a non-technical public.

The human system is so complicated that the doctor is excused if he somtimes doubts his diagnosis or treatment. To the general public, however, a heating or ventilating system is merely a matter of pipes and ducts. Possibly it is our fault that the public is not brought to a realization of how complicated our heating and ventilating systems really are, that the underlying principle of all our systems, the law of flow, is one in which the forces are so inextricably involved as to defy a precise mathematical expression and that even to formulate an equation having a semblance of rational basis we must build it on an assumed condition of flow which possibly never exists.

As the analogy has already been made between the animal body and our heating and ventilating systems, it may be of interest to note what a strong resemblance really exists. The food we eat is our fuel. It undergoes the same process of combustion and evolves heat to supply the heat losses of our bodies. The heating system has its arteries and veins carrying the circulation. To consume the fuel properly and carry off the impurities the system breathes air through its chimney, and so that all parts may properly function the entire operation is directed by the nerve system of thermostatic control. Like the human body, it is lusty and strong in its youth, but with advancing years deposits accumulate in its veins, circulation becomes labored and slow and shows symptoms of high blood pressure. To offset its weakness the owner gives it the tonic of added fuel. To meet the increased demand the boiler gasps for breath through its soot-clotted lungs and with the increased pressure something is bound to snap. When it does so the system has its first stroke of apoplexy.

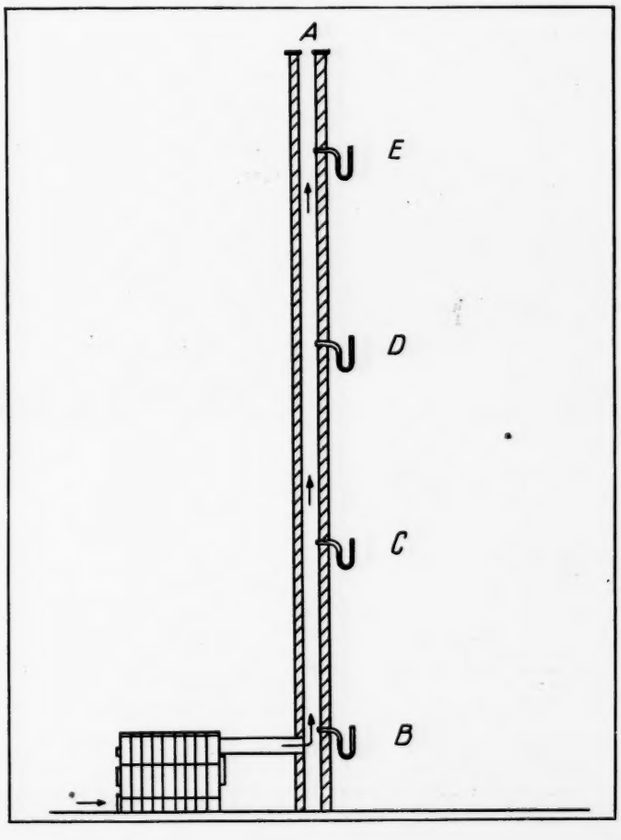
QUESTION 23. Would you advise using brass piping at all times for domestic hot water? *R. A. M.*

ANSWER. In so far as corrosion is concerned the brass piping would be best, but I believe that in some sections of the country the water is of such nature that excessive deposits are formed. I hope to be able to give a further discussion on this and the friction in brass and copper piping in an early issue. In the meantime I will appreciate hearing of the experience of any readers.

QUESTION 24. Just as a matter of interest, will you discuss the following question in your column. We know that the heated air in a chimney is lighter than the outside air and, therefore, has less pressure. Also that the excess pressure on the outside causes the air to flow into the base of and up the chimney; but the same argument should hold good for the extreme top and thus cause the air to flow into and down the chimney. *C. R. T.*

ANSWER. The many kind letters received from my readers has resulted in a generally friendly feeling among those who share an interest in these columns, and I am, therefore, inviting discussion on this question. I will be glad to publish the replies either under your name or initials. The problem is shown graphically below, where AB represents the chimney. C. R. T.'s contention is that if a draft gauge were inserted at the point B it would show a negative pressure. In other words, if an opening were made in the chimney wall, the outside air would be drawn inward.

His further contention that the same argument will hold good at any other point, as C, D and finally at E, which is at an infinitely small distance below the top; that if it holds good at E, it should also hold good at the extreme top and the air should flow into and down the chimney.



News of the Month

A 28% Increase in Gas Heating Reported at 13th Convention of A. G. A.

Probably the most striking feature of the thirteenth annual convention and exhibition of the American Gas Association, held in Atlantic City, October 12-16, was the feeling of satisfaction prevalent because of the showing which the gas industry has made in spite of the current depression. Not only has the industry held its own in volume of business and in net returns, but success has met the efforts directed toward finding and developing new uses for gas. This is especially true of the use of gas for house-heating.

Statistical bulletin number 9 of the association issued in October sums this up well when it states:

"Perhaps the most noteworthy feature to be observed from a study of developments in the manufactured gas industry during 1930 is the inherent soundness and stability of the industry.

"This factor is emphasized not only by comparisons with other industries in general, but is most strikingly indicated in relation to other fuel industries which are more or less competitive in nature."

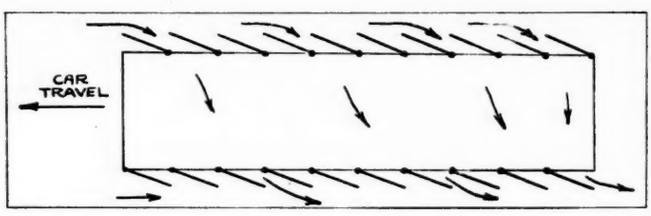
This same bulletin presents a table showing that the volume of manufactured gas sold in 1930 for house-heating increased nearly 28% over 1929. What is still more notable is that of the four principal uses to which manufactured gas is put, house-heating was the only one which showed an increase during 1930.

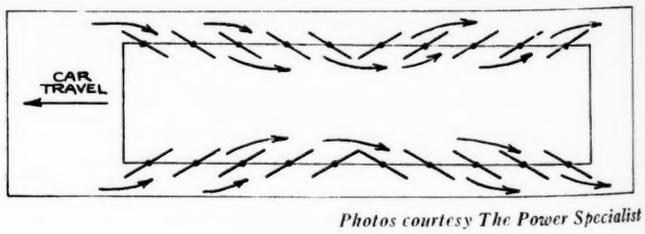
While the use of manufactured gas for house-heating has not reached a volume comparable to the amounts used for other domestic and for industrial and commercial purposes, it has become a sizable quantity, totaling nearly 30 million m.c.f. in 1930. Leaders of the industry seem well aware of the importance of the house-heating load and active development plans are under way.

Speakers at the convention stressed principally the importance of looking to the future. There was no bemoaning of mistakes of the past, for this industry has been exceptionally fortunate in having laid well considered plans which have been successfully carried through. If anyone in the industry doubts that it has a future he did not make his presence evident during the course of the convention.

Even though the industry is in a favorable position and has shown substantial progress, the depression did not fail to make itself felt in the attendance, which attracted only approximately half of the record crowds which have attended the meetings during the past few years.

Both the general and sectional meetings were well attended but the absence of large crowds was most noticeable at the exhibit. The exhibition itself was very carefully planned and the great main floor





Photos courtesy The Power Specialist

(Upper left) One of the subway cars for the new city subway system in New York. Cars are heated with electric heating units and well insulated to reduce heat loss. (Upper right) Interior of one of the new cars which seats 60 and stands 220. (Lower left) Sketch showing method of ventilating new cars. The air travels across the car and out the other side. (Lower right) The ventilation of the old subway cars was arranged for in this manner.

of the auditorium was filled. The fact that so many manufacturers were willing to exhibit their products in spite of the discouraging business conditions of the present year is a tribute to their faith in the prospects of the industry. Apparatus for using gas for house-heating occupied a prominent place in the exhibition. At least thirty items of such equipment were present.

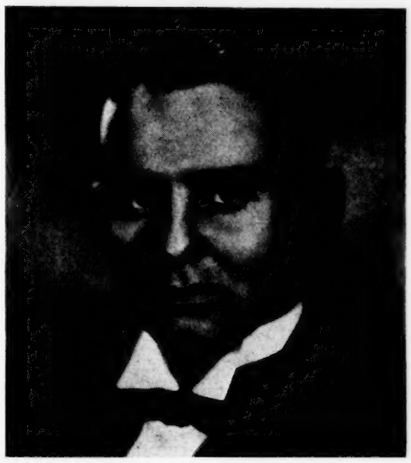
Fan-driven warm-air units specially designed for use with gas attracted considerable attention, and it seems apparent that the use of such units is becoming increasingly popular. A number of new gas conversion burners were also shown.

The work of the association's testing laboratory in approving new devices gives further evidence of the increasing number of heating appliances which are coming on the market. The laboratory's report showed a large increase in the number of such devices submitted for testing during the year. The laboratory of the association continues to grow and those in charge called particular attention both to its increasing usefulness to the industry and to the increased recognition which is being accorded to its work by those outside the industry.

The accomplishments of the association's commercial and industrial sections are always of interest because of their contacts with space heating.

The rapid increase in the use of gas for heating has brought interesting commercial problems. Among these none is more important or is receiving closer study than that of the relations between gas companies and dealers who sell gas-using apparatus commercially.

In recent years there has been a considerable tendency for gas companies to become retail dealers and installers of equipment. In many cases this tendency has brought about bad feeling between existing retail dealers and installers and the gas companies. Careful study has been given to the problem by the general committee on allied trades headed by Col. O. H. Fogg. Recognizing the importance of the subject, general policies have been drawn up during the past year which have not only been endorsed by the American Gas Association but by some of the trade associations representing interested tradesmen and contractors. As a result of study given to the subject a number of gas companies have put dealer cooperation plans into practice. The report of the committee on trade and dealer cooperation under the chairmanship of Hugh Cathrell summarized some of the findings of the committee. Mr. Cathrell also presented a paper before the commercial section illustrating the values which may be obtained from dealer cooperation plans by citing the results secured in Brooklyn where such a plan is in operation. A subcommittee of the association committee on house-heating also presented the results of its studies as applied particularly to heating contractors and illustrated some of the plans which have been put into use.



Samuel Insull, Jr., chairman of the commercial section, American Gas Association; president, Midland United Company; president, Midland Utilities Company, and vice-chairman, The Peoples Gas Light and Coke Company, Chicago.

Samuel R. Lewis, a consulting engineer of Chicago, aso presented a most interesting paper before the commercial section under the title "What is Ahead in the House-Heating Field." Mr. Lewis visioned the day when insulation would be much more generally used in residential building construction than is now the case and felt that the gas industry would benefit by it. He also feels that central station heating by steam or hot water as a means of furnishing automatic heat would not have a place in the future of house-heating. He feels that gas occupies an especially advantageous position and that it is an ideal commodity for use in central station heating. He predicted that residential heating would be automatic from one end of the year to the other; that changes of air would be provided for; that in the warmer climates houses would be cooled in summer just as unobtrusively as they are now heated in winter. He felt that the use of gas for cooling purposes, especially where dehumidification can be separated from cooling has outstanding possibilities. Mr. Lewis also feels that circulation of cooled water through radiators for summer cooling is to be expected in residential cooling. He predicted that specially designed appliances for use with gas would take the place of the practice of converting appliances intended for use with other fuels. The following quotation is of interest:

"The contractors for warm-air heating, like the contractors for steam and hot water heating, will cease being engineer-salesmen, but will be salesmen of workmanship rather than salesmen of proprietary materials.

"Designs of the installations will be made by architects and engineers, and these designs will, as is the case at present with steam and hot water heating, practically be universally adaptable to any make of proprietary apparatus.

"The larger, more costly house will use steam or hot water to carry the heat from the gas fire to the room.

"An indirect radiator, or several of them, with fans, will provide ventilation.

"The smaller, less costly houses will use warm-air heating, recirculating the internal air but with a designed cold air intake, just as with the steam or hot water systems, for air renewal and odor abatement purposes.

"All three methods of transferring the heat from the gas to the rooms will be mechanically accelerated so that pipes and ducts will be very small and inconspicuous, with electric vacuum pumps on the

News of the Month

steam systems; with electric fans on the warm-air systems.

"A production warm-air heating unit of small size with few if any ducts will be developed. The experienced contractor may look at the plans or at the house and say, 'that house needs four units, or it needs six and one-half units—call it seven to be safe,' and will straightway take these low cost units from stock and will simply connect them up with gas, electricity and chimneys. When gas warm-air heating develops such a unit it will begin to become profitable to someone besides the gas company."

Mr. Lewis presented recently compiled figures estimating the cost for cooling and heating a house under present conditions. These figures appear elsewhere in this issue.

The new chairman of the commercial section is Samuel Insull, Jr., of Chicago, while the new vice-chairman is Walter Beckjord, of Boston.

One of the projects sponsored by the industrial gas section, and which has been under way during the past summer, is of special interest. The committee on industrial gas research, under the chairmanship of N. T. Sellman, New York, has caused gas-fired cooling installations to be put into houses at Pelham, N. Y., and Chicago. Mr. Sellman reported on the results obtained in these two installations. These results appear elsewhere in this issue.

District Steam for Pennsylvania Station

The largest isolated boiler plant on Manhattan Island has given way to district steam. According to a recent announcement, the Pennsylvania Railroad Company has contracted with the New York Steam Corporation for all the steam requirements of the Pennsylvania Terminal, the service plant of the railroad, and the Pennsylvania Hotel, all in New York. Approximately 500,000,000 lb. of steam per year will be delivered under the contract; 40,000,000 cu. ft. of building space and thousands of railroad cars will be serviced. Use of district steam eliminates the handling and burning of more than 40,000 tons of coal at and the removal of almost 10,000 tons of ashes from the old plant.

A. O. B. A. Protests Award of Federal Contract to Steam Utilities

In a statement made October 13, Walter F. Tant, president of the American Oil Burner Association, vigorously protested against alleged arbitrary rulings on the part of the supervising architect's office at Washington in not permitting oil, gas and coal-fired equipment manufacturers to enter bids in competition with district steam. The award in question was that for the heating of the new parcel post building in New York. The contract was let to the New York Steam Corporation.

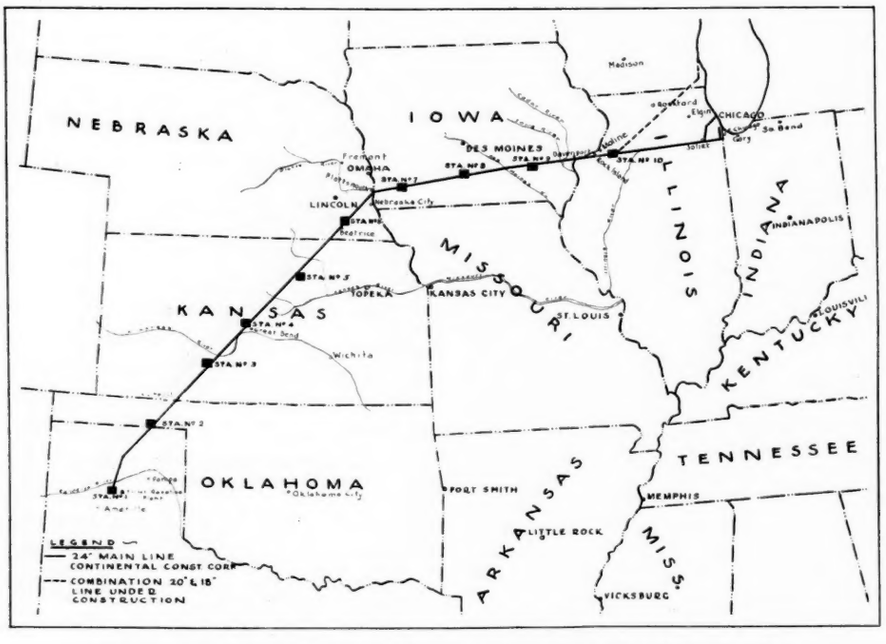
Mr. Tant's statement, in part, follows:

"This association emphatically has no quarrel with competing fuel interests. All it asks for is free and open bidding on all heating contracts. It maintains that in the interest of governmental economy, contracts involving millions of dollars should be let to the lowest responsible bidder, yet in New York this sound business practice was ruthlessly thrown overboard and heating contracts were arbitrarily awarded to a local steam company, without coal, oil or gas equipment manufacturers even being permitted to bid!

"A month before bids were scheduled to be received on the new parcel post building in New York, a responsible manufacturer of oil burning equipment called the government's attention to newspaper stories saying that the heating contract would be awarded to a steam corporation and requested that an addenda be issued to permit competing heating methods to enter a bid. Not only did they request permission to bid, but stood ready to guarantee a saving of $30,000 a year on heating costs over the rates on file for the steam company with a public service commission. This request was ignored until repeated protests brought this curt reply from the office of the supervising architect in Washington. 'The experience of this office in operating some 1,500 buildings, is considered to be sufficient guide in protecting the interests of the government in this respect.'

"Does this represent the attitude of the government architects toward the American taxpayer at a time when every effort is being made to reduce the expenses of the government?

"Repeated protest from this association and from individual mem-



The route of the 900-mile Chicago natural gas pipe line showing the ten compressor stations

bers, have resulted in a continual shifting of responsibility by government officials and finally a flat refusal to receive bids from oil burner manufacturers. What this association wants to know, is why the oil burner industry is not permitted to bid on government jobs, especially in view of the fact that in most instances the oil burner manufacturer can supply heat and power at a considerably lower figure than contracts recently awarded by the government called for. This industry believes that it is being discriminated against, and proposes to learn the reason."

Pennsylvania Railroad Operates Five Ice Cooled Diners

Several months ago a description was given in these pages of the ice cooled diner built by the Pennsylvania Railroad. Results were apparently satisfactory, for the company has subsequently made four more similar installations and now has five ice cooled diners in operation on the following trains: *Congressional Limited*, New York to Washington and Washington to New York; *Liberty Limited*, Altoona to Washington and Washington to Altoona; *Senator*, Washington to Boston and Boston to Washington.

Pittsburgh Engineers Hold First Meeting of Season

The first meeting of the season was held by the Pittsburgh chapter of the A.S.H.V.E., at the Keystone Athletic Club, October 5. Seventy-two members and guests were in attendance.

W. W. Stevenson, F. A. Gunther and Paul Edwards were appointed as a nominating committee to report at the November meeting.

The meeting was addressed by Willis H. Carrier, national president of the society, who spoke on Servicing the Human Power Plant.

758 Federal Building Projects Under Way

Federal public building projects under the administration of the Treasury Department, totaling $300,000,000, are now under contract, according to reports made to President Hoover. A total of 758 building projects, with an estimated cost of $453,000,000, have been authorized. Reports up to July 16 showed a total of 57 contracts completed at a total cost of $25,326,876. Contracts let but not completed aggregate 192, with an estimated cost of $135,637,366. Plans have been completed and contracts are being put through on 61 buildings, with a total estimated cost of $44,249,800. Sites have been acquired and plans are being prepared for 192 buildings, with a total estimated cost of $181,353,023. Sites have been acquired or are in negotiation for 100 projects, to cost $32,301,841. Sites are being sought for 156 buildings, estimated to cost $34,871,000.

N. Y. U. Starts Course in Domestic Appliances

In cooperation with the American Gas Association, New York University is introducing a course of instruction in domestic gas appliances. The course will be under the direction of Mrs. Frieda Winnig, head of the Home Economics Department. Classes will be held Friday of each week for six weeks. The fourth week will be devoted to house-heating and cooling, with the following subjects and speakers: Gas, W. B. Garrison, American Gas Products Company; Oil, H. F. Tapp, American Oil Burner Association; House Cooling, J. R. Denise, Consolidated Gas Company; Coal, W. R. Zuhlke, American Radiator Company; Controls, A. P. Mudgett, Minneapolis-Honeywell Regulator Company.

COMING EVENTS

NOVEMBER 10-13, 1931. Twenty-Second Annual Convention and Educational Exhibition of the National Association of Practical Refrigeration Engineers, at the Houston Municipal Auditorium, Houston, Texas.

NOVEMBER 16-21, 1931. Third International Conference on Bituminous Coal. At Carnegie Institute of Technology, Pittsburgh, Pa. Chairman, Thomas S. Baker, President of Carnegie Institute of Technology.

DECEMBER 2-5, 1931. Convention of the National Warm Air Heating Association, Washington, D. C. Headquarters at the Mayflower Hotel.

JANUARY 25-28, 1932. Joint-Annual Meeting of the American Society of Heating and Ventilating Engineers, and the American Society of Refrigerating Engineers, at Cleveland.

JANUARY 25-28, 1932. Second International Heating and Ventilating Exposition, at Cleveland, Ohio.

JANUARY 25-30, 1932. National Association of Sheet Metal Contractors, Louisville, Ky. E. M. Pope, Chairman, Publicity Committee, 58 W. Washington St., Chicago.

APRIL 11-16, 1932. Ninth Annual Convention and Oil Burner Show of the American Oil Burner Association, Mechanics Building, Boston, Mass.

Aeberly New President of Chicago Chapter

At the regular monthly meeting of the Illinois Chapter of the A.S.H.V.E., October 12, John J. Aeberly was elected president, and Chas. W. DeLand, secretary. A. G. Sutcliffe, E. Mathis and H. P. Reid were elected as the board of governors.

The principal speaker of the evening was Prof. G. L. Larson, of the University of Wisconsin, who discussed infiltration tests at the university.

High Temperatures in September

The records of sixty years show few Septembers when the monthly mean temperature was higher than that of September, 1931. At New York it was 4.4° above normal; at Boston, 3.6°; at Pittsburgh, 3.9°; at Chicago, 6°, and at St. Louis, 6.4° above normal. The average temperature at all these cities, except Boston, was warmer than that of any September since 1881, when a maximum of 100° was recorded at New York. But September, 1931, will long be remembered in the interior because of five days with a maximum temperature of 90°, or higher, at Pittsburgh; nine such days at Chicago; fifteen at St. Louis, but only two at New York.

Correspondence

Air Conditioning Factors for Residential Application

EDITOR, HEATING AND VENTILATING:

Prompted by a sincere interest in the future welfare of the rapidly developing air conditioning industry in a recent editorial you said in part:

"1. The very fact that the term 'air conditioning' is coming into glib use so swiftly gives rise to possible dangers.

"2. If the word continues to be popular and if it can be sold, lack of ability is not likely to deter many unscrupulous people from capitalizing on its popularity."

A recently published dispatch, observed in metropolitan dailies indicated that the chief executive of the nation specifically identified residential air conditioning as one of the new industries that will tend to rehabilitate the economic structure of the country.

Residential air conditioning is not coming—it is here.

Most of an industry's problems are those of selling. Brains and capital can overcome almost any manufacturing problem. The problem of circumventing unfair competition has made headway in some industries.

There can be no arbitrary ruling, by which everyone will abide, as to what constitutes residential air conditioning. Partial air conditioning will suffice for some people, perhaps mainly because of financial limitations.

An editorial in a contemporary publication appropriately remarks: "No one is going to resign himself to walking just because he cannot afford a Rolls Royce; perhaps more applicable still, no one will refuse to install modified air conditioning just because he cannot afford the ultimate. Some degree of air conditioning is better than none at all.

"The system that is economically successful for a large building, a theater, a hotel or even a palatial mansion may be entirely too complete to be justified in the case of a modest home."

The fabricated air conditioning unit may be complete, or it may be incomplete, but the fact remains that the claim to its being an air conditioning unit will be proffered.

An important point at issue is how to codify for general acceptance, the degree of air conditioning that will be accomplished by the various fabricated units. Codification to circumvent absurd claims and unethical practices is effectively accomplished in other industries.

For example, it is the veriest commonplace that in the automotive industry, each unit is designated as having a specific horsepower, and the industry positively identifies each unit as a four cylinder, a six cylinder or an eight cylinder motor, as the case may be. Again, the diamond merchant does not allow his competitor to undersell him by vague description. The diamond is specifically identified as of so many carats or points, and its quality is ranged from a blue white stone down to a canary. The measure of quality and quantity is so clearly indicated that an underselling competitor cannot claim quality of product without direct misrepresentation.

Making inequality of residential air conditioning units quite obvious can be done by developing a sensible and logical method of rating each type of fabricated unit. The pro and con regarding whether it is or is not an air conditioning unit only develops a controversy. In controversy no man wins.

The following definition of factor —one of several elements or causes that produce a result—prompts the suggestion that residential air conditioning units be rated upon a *factor* basis.

Thus, a list of factors could be set up, similar to the following suggested list:

1. Measured and complete air distribution.
2. Provision for control of temperature for winter.
3. Cleaning of air (by filtration or washing).
4. Automatic supply, or automatic control of humidity for winter.
5. Cooling effect by air circulation for summer.
6. Provision for summer cooling (by mechanical refrigeration, or other source of refrigerating effect).
7. Dehumidifying or control of relative humidity for summer.
8. Ionizing, deionizing and deodorization.
9. Treatment of the carbon dioxide factor.

In the light of present knowledge it appears that factors 8 and 9 will rarely be given consideration in residential installations.

If a manufacturer fabricates a unit, designed merely to deliver air under positive pressure, and with temperature control for winter, it may be a misnomer to call it an air conditioning unit, but, having a certain apparent similarity, i.e., heating unit, blower, conduits, and thermostatic control, he has a legal if not a moral right to enter into the impending and so-called abuse or misuse of the term air conditioning, and he will possibly do so. At least his unit gives consideration to some physical characteristics of the air.

Herein comes the advantage of codifying the degree of air conditioning for general acceptance. To argue whether it is or is not an air conditioning unit, entails the controversy before mentioned, but to appropriately and convincingly acknowledge it as a two-factor air conditioning unit, definitely classifies it

Second International Heating and Ventilating Exposition Supplement

Continuing the policy inaugurated at the time of the First International Heating and Ventilating Exposition in 1930, HEATING AND VENTILATING will publish the Second International Heating and Ventilating Supplement in January, 1932. It will be mailed to all regular subscribers, without extra charge, and will contain the program of the meetings, guide to the exposition and other valuable features of interest and value both to those who will attend the exposition and those who will be unable to be present.

By this method, the unit and installation which assures measured and complete air distribution, automatic temperature control for winter, cleaning of air by filtration or washing, automatic supply or control of humidity for winter, cooling effect by circulation for summer, mechanical refrigeration for summer cooling, and dehumidifying or control of humidity for summer, is essentially a seven-factor air conditioning installation.

MONT H. SMITH, JR.
LANCASTER, PA.

Use of Nominal Diameters in Water Supply Piping Design

EDITOR, HEATING AND VENTILATING:

Mr. Crocker's kindly criticism[1] is highly appreciated and his point relative to the use of the nominal pipe diameters in one of the tables of my article[2] is well taken. Criticisms of this nature go far to aid in arriving at a proper solution of our complex problems.

The formulas developed in the article were but a tentative offering to arrive at some standard rule of practice on a subject where a multiplicity of rules prevails. It was with a feeling of trepidation that the nominal pipe sizes were used, and possibly an explanation should have been offered at that time. It may be remembered that the number of fixtures supplied by the various sizes of pipe were taken from a composite layout compiled from a mass of confusing data and from some personal observations. These observations, or tests, consisted largely in timing the flow from various sized fixtures in several installations. The actual discharge from the different sizes seemed to follow rather closely along the values of column C of Table 1 of my original paper. It was impossible to reconcile these results with the formula $D^{5/2}$ when the actual pipe diameters were used, but the values did follow rather closely by using the nominal diameters. This led to the conclusion that possibly the faucets and taps were factors in the friction created, but up to the present time I have not had an opportunity to verify this.

For this reason the nominal diameters were taken. Their use, however, does not affect Table 3 of my article, which is purely empirical, nor does it affect Table 4, which is based on the actual diameters. Probably later research results may develop a better method of solution and it can only be through the aid of helpful criticism and discussion.

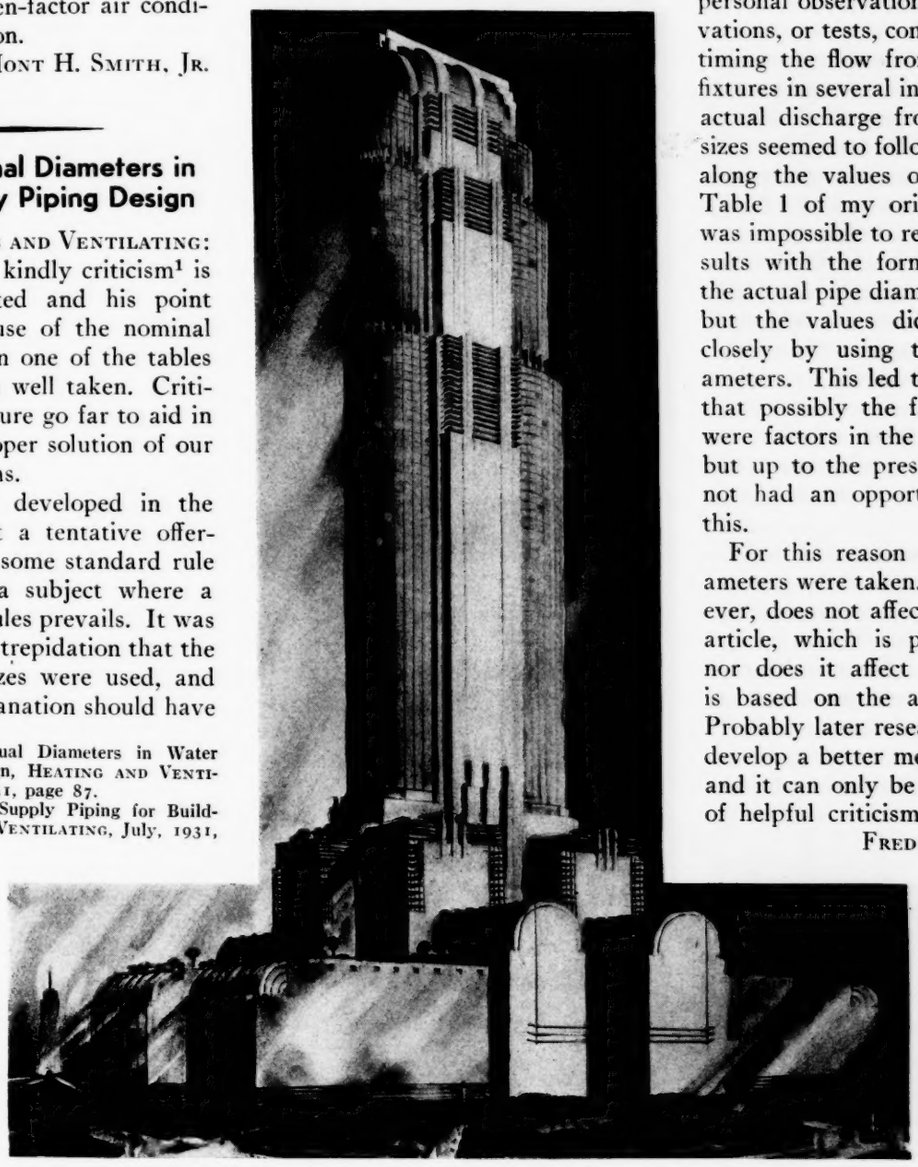
FRED W. HANBURGER.

[1]Nominal vs. Actual Diameters in Water Supply Piping Design, HEATING AND VENTILATING, October, 1931, page 87.

[2]Designing Water Supply Piping for Buildings, HEATING AND VENTILATING, July, 1931, page 56.

Theater Reference Number

The Theater Reference Number of HEATING AND VENTILATING will be published next month. It will contain articles and data on theater air conditioning and heating system design and operation, and will be the fifth of the reference number series. Previous issues were devoted to schools, public buildings, industrial buildings, and office buildings.



WHEN 2,000 FT. BUILDINGS ARE BUILT, HERE'S THE WAY THEY MAY LOOK

New Yorkers of 1981 or thereabout will live in superskyscrapers perhaps 2,000 ft. high, in an ideal climate as to sunlight, temperature, humidity and atmospheric purity, controlled by mechanical means, Irwin S. Chanin, architect and engineer, head of the Chanin organization, recently predicted.

The walls will be of metal or glass, probably the former. Fifty or sixty of them will house a population considerably greater than that now living on Manhattan Island.

Such a building would occupy a ground area of 400,000 to 500,000 sq. ft., and would be at least half a mile from the next building.

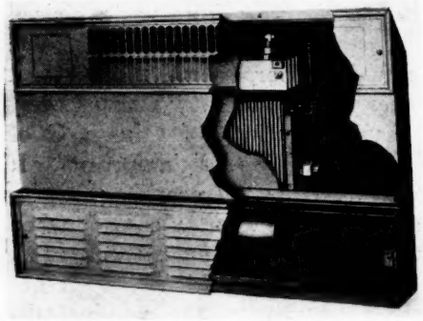
The huge shaft of the building is devoted entirely to residential uses. Communal kitchens and dining rooms on each floor will replace individual facilities for preparing and serving food. Artificial lighting transmits a highly efficient amount of ultra violet rays. The air is chemically pure. Temperature and humidity are always maintained at scientifically ideal standards.

The base of the building is devoted to the businesses and activities supporting the residential portion of the building, which in reality is a complete city. The roof of the base portion of the structure is here shown planted. With the development of a braking device or the perfection of the gyroplane, it may serve as a landing space for aircraft.

New Equipment

Combination Steam and Electric Heating Unit

A combination of two types of heating element in the same built-in cabinet or in free standing cabinets,



Air-Way combination unit

is announced by Air-Way Electric Appliance Corp., Toledo, Ohio. In the combination Aeriet an electric and steam heating element can be operated in conjunction with each other, or separately if desired. The unit is particularly adaptable to installations where an auxiliary heater is needed for damp and chilly days before the steam is turned on. It makes unnecessary the use of a separate portable electric radiant heater.

The combination unit is furnished in several sizes and capacities ranging from 1500 watts to 5000 watts in the electric element, and from 20 sq. ft. to 80 sq. ft. of direct radiation in steam heating capacity.

The manufacturer states that a simple air washing and humidifying attachment can be furnished if desired.

Weil-McLain Radiant Recessed Radiator

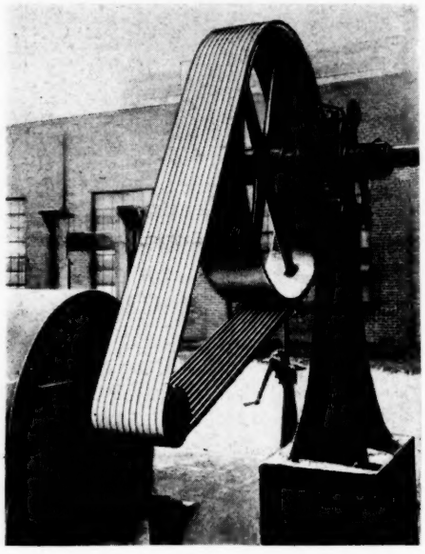
Weil-McLain Co., Manufacturing Division, Erie, Pa., is placing on the market its radiant convectant recessed radiator, made of cast iron. The front of the radiator, which appears flush with the wall, constitutes the radiator part of the heater and also the grille for the cast iron convection unit located at the bottom inside portion of the panel. The radiator stands on two feet at each end.

The recess in which the radiator is to be placed is to be insulated.

Units are available in ratings ranging from 11.6 sq. ft. to 58 sq. ft.

Vulco Rope V-Flat Drive

The Gates Rubber Co., Denver, Colo., has placed on the market the



Vulco rope V-drive

Vulco rope V-drive, designed to make possible lower installation cost, applying particularly to drives of reasonably high speed ratios and short shaft centers. The drives are suitable for almost all power transmission requirements. Usually the equipment needed for conversion to this type of drive will be the motor sheave and the necessary Vulco rope. The old flat pulley will serve satisfactorily as the driven pulley.

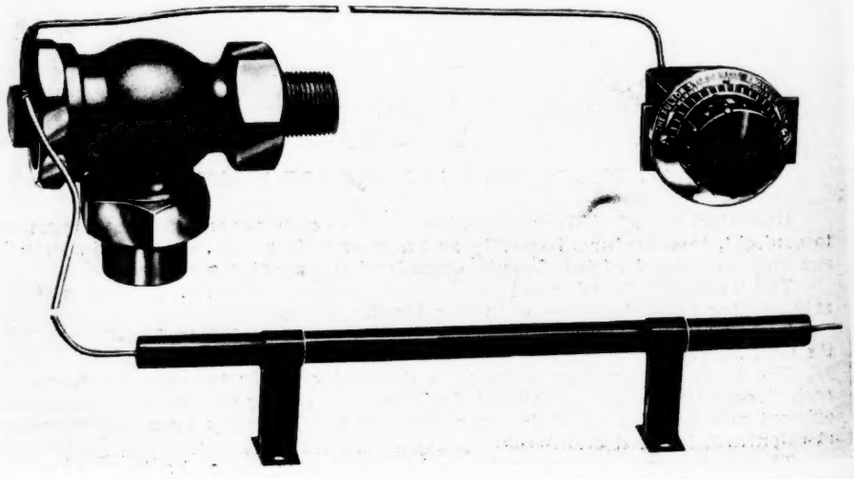
Wrought Iron Welding Elbows

Announcement has been made jointly by the Locomotive Terminal Improvement Co., Chicago, and the A. M. Byers Co., Pittsburgh, of a line of wrought iron welding elbows, known as Weldells, in sizes from 2 in. to 12 in.

The elbows are manufactured with the same radius and center-to-face measurements as standard radius fittings. In the forging, a tangent is formed on each end, making the elbows interchangeable with standard fittings, and the ends are beveled 45° for welding. Stock sizes include both standard and lightweight (10 gauge) sections. The elbows are forged from wrought iron plate, with a smooth, uniform internal diameter and a reinforcing rib along both the outer and inner radius of curvature.

New Fulton Sylphon Radiator Valves

The Fulton Sylphon Co., Knoxville, Tenn., has announced two new improved types of radiator controls. One is designed for concealed radiation which can be enclosed entirely in a radiator cabinet. For exposed



Fulton Sylphon radiator valve for concealed radiators

radiation the company announces a further refinement of their No. 875 valve.

These valves can be used on any two-pipe steam, vapor or vapor-vacuum heating system. They are furnished in both globe and angle types.

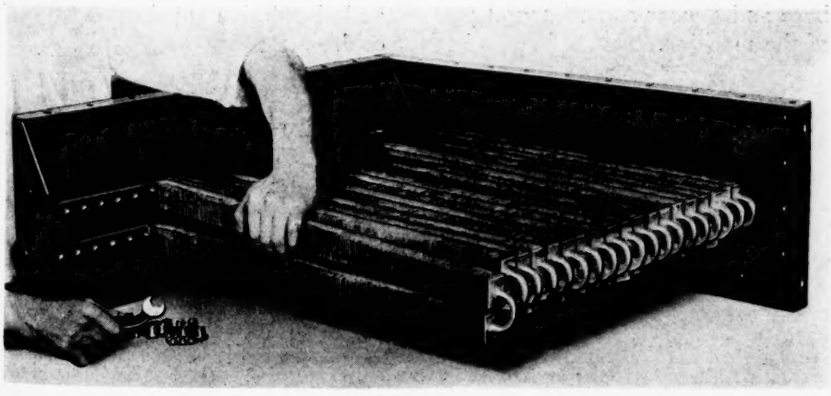
Protective Paint for Pipe Lines

Announcement has just been made by the American District Steam Company, North Tonawanda, N. Y., that the company has perfected a protective paint for use on steam and hot water pipe lines. The product has been named Adsco Pipe-Kote 505, and according to the manufacturer, is impervious to any degree of heat generated by steam; is practically immune to the action of moisture, dilute acids and alkalis, and while it produces an extremely hard, tenacious coating, it is sufficiently elastic to expand and contract with the pipe without cracking or peeling.

While Pipe-Kote is especially recommended for use on steam and hot water lines, it works with equal effectiveness on water mains, stacks, boiler fronts, and all other surfaces exposed to extreme or rapid changes of temperature and atmospheric conditions.

Featherfin Heating Surface

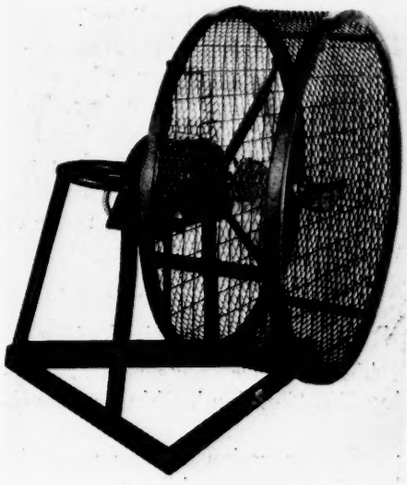
L. J. Wing Mfg. Co., 154 West 14th St., New York, is using a new heating element called the Featherfin in its line of Featherweight unit heaters. The element is of the fin and tube extended surface type, tubes being of return-bend design of seamless drawn-copper. Flat fins, with their greatest dimension in the direction of air flow, are forced on to the tubes without crimping or corrugations. Headers are of steel, tubular in design. Tubes are secured to the headers by a mechanical joint consisting of a compression union comprising a brass ferrule and a nut.



Wing Featherfin heating surface for unit heaters

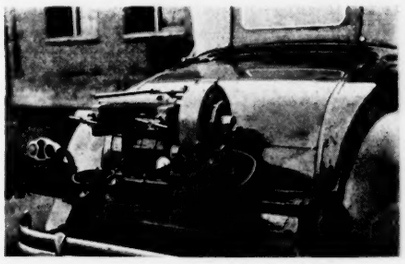
Floor Level Aerospot

The American Propeller Co., a division of the Bendix Aviation Corp., 401 Bendix Drive, South Bend, Ind., has placed on the market the floor level Aerospot portable propeller fan for use where a powerful blast is desired, such as in ice cream plants, laboratories, dyeing rooms, and other such installations. The unit can be fastened to the wall or ceiling.



American Propeller Company floor level Aerospot

Aerospot is made in two sizes, with ¼ hp. motor and 24 in. propeller, and 1/6 hp. motor with 20 in. propeller, both turning at 1725 r.p.m.



Axelson portable threader

Axelson Portable Threader

The Axelson Mfg. Co., Los Angeles, Calif., has announced the Axelson portable pipe threader designed to thread ½ in. to 2 in. pipe. The illustration shows the threader mounted on the rear of an automobile. The machine itself weighs less than 190 lb. It is powered by a reversible G. E. motor which can be used on any 110 volt circuit.

Sphinx Conversion Burner

C. L. Bryant Corp., 10511 Churchill Ave., Cleveland, Ohio, is marketing the Sphinx gas conversion burner designed especially for warm-air furnaces. The unit, according to the manufacturers, is sold only for furnaces for which it has been adapted and approved at the factory. A feature of the unit is the automatic regulation of the volume of air supplied to the amount of gas being burned.

The burners are available in four sizes, with capacities ranging from 410 sq. in. to 690 sq. in. of leader pipe, on the standard code basis. The figures apply to the maximum capacity of the units.

Spencer Steel Tank Heater

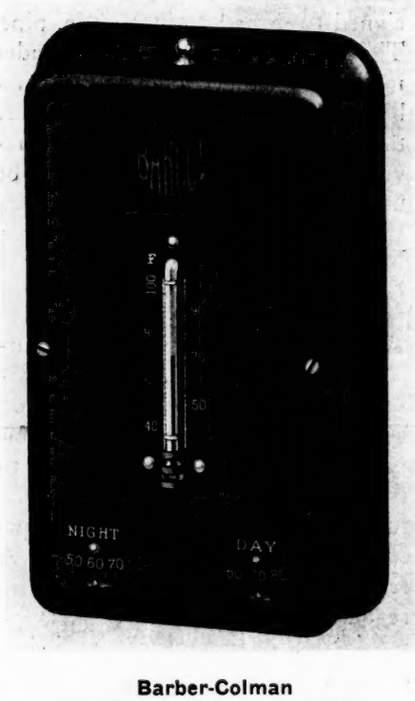
To meet the demand for hot water at all times, and under high pressure conditions found in the larger

cities, Spencer Heater Co., of Williamsport, Pa., has announced a heavy duty steel tank heater. The heater is built of copper-bearing rust-resisting steel and has extra heavy Toncan iron tubes. It is guaranteed to withstand 125 lb. working pressure.

A feature of the device is the sloping grate and automatic gravity feed. The fire bed is said always to be at a uniform depth, supplying the water with uniform heat at all times.

Barcol Two-Temperature Thermostats

A two-temperature thermostat, designed for use in buildings where it is economical and possible to have



Barber-Colman two-temperature thermostat

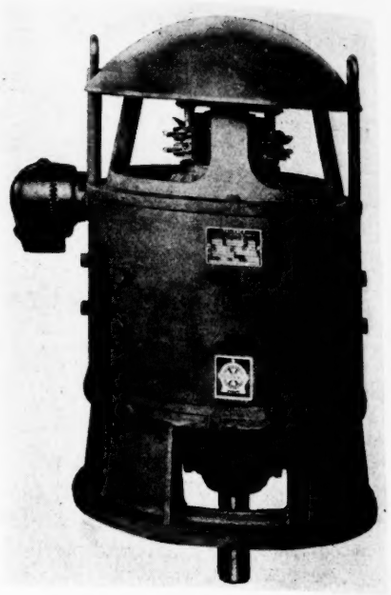
the temperature throughout, or in any parts of, the building lower at night than in the daytime, has been announced by Barber-Colman Co., Rockford, Ill.

The device consists essentially of two bimetallic-element units such as are found in the ordinary room thermostat. One element is adjusted to control a range of from 60° to 80° and the other the relatively lower range of from 50° to 70°. If desired, other ranges can be supplied to meet requirements. A switch inside of the thermostat, actuated either by electro-magnets or by a manual lever on the top of the case, determines which of the two units shall control the temperature of the room. In installations where large numbers of these thermostats are used in the same building, change of control may be accomplished simultaneously in all thermostats by means of the switching magnets with which each is equipped. These magnets are connected to an electrical system controlled by a master switch in the engineer's office, or other convenient place, making possible an easy means of changing control from one range to the other. The manual switch upon each thermostat makes possible the placing of individual instruments on either day or night range by occupants of the room at any time. This is convenient if a room is to be occupied during the evening when the rest of the building has been placed under control of the night range of the thermostat.

Reliance D.C. Vertical Motors

The Reliance Electric & Engineering Co., Cleveland, Ohio, has developed the type T d.c. motor for vertical operation in sizes up to 50 hp., 1150 r.p.m. The motors are provided with a ring base for mounting and a drip cover to protect them from falling dirt and chips and from dripping water, oil or other injurious solutions.

Where it is desirable the motor can be mounted direct to the machine, being driven without the ring base and appear as an integral part of the machine.



Reliance vertical motor

Amply large bearings are used to take up the thrust load or weight of the armature. Two heavy eyebolts are provided to make handling easy. In all other ways the construction is the same as the type T, d.c. heavy-duty motor for horizontal operation.

Truscon Ferroclad Insulation

Truscon Steel Co., Youngstown, Ohio, has announced Ferroclad insulation, which is available in any desired thickness. The material consists of any standard make insulation the buyer desires with outer layer of steel tightly joined to the insulation as a unit. The steel may be of any desired thickness, from 24 to 20 gauge, either black, galvanized or furniture steel. Non-ferrous metals can also be supplied.

The insulation fills a definite need offering rigidity, physical strength and insulation against heat and cold.

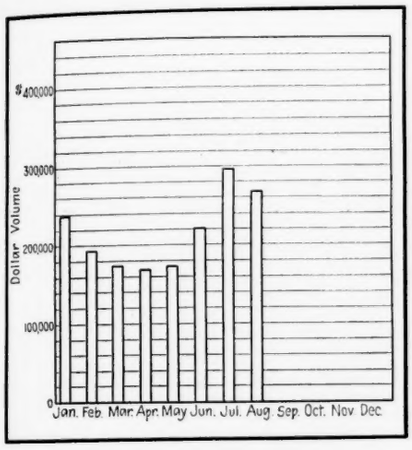
Truscon Steel Company Ferroclad insulation

Statistical Service

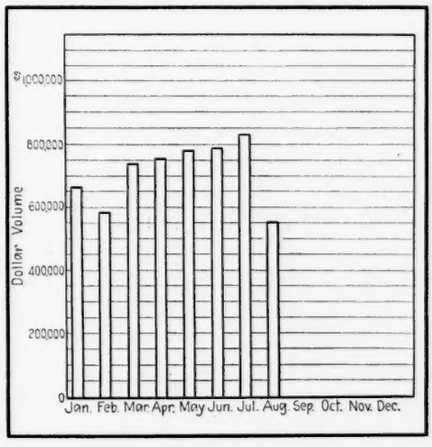
THIS month, production data on six additional groups of commodities make their appearance. The volume of sales of air washers, unit heaters, unit ventilators, fans and blowers, indirect heating surface and stokers are presented in graphical form. The graphs include figures since January 1, 1930, and are based on data collected by the Department of Commerce.

The Department of Commerce is collecting more and more data covering the heating, ventilating and air conditioning industries as time goes on. Only a few years ago it was impossible to obtain any reliable figures on production in these industries, the only available statistics being those collected by the Bureau of Census on manufacturing establishments, and in these heating apparatus was classified as "Stoves, Ranges, Heating Apparatus and Steam Fittings." These data were so confused that they were almost worthless.

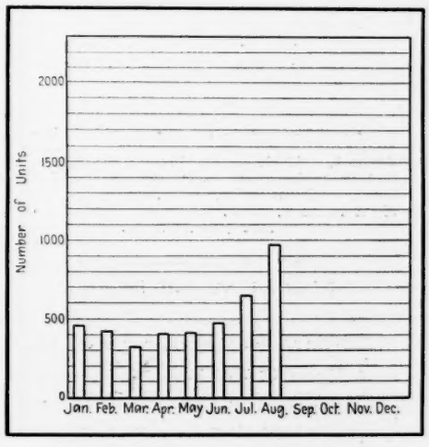
All this, however, has been changed, and, in spite of the difficulties in determining the best units in which production, sales and shipments can be reported, and in spite of the obstacles in the way of collecting the figures, the department is succeeding admirably.



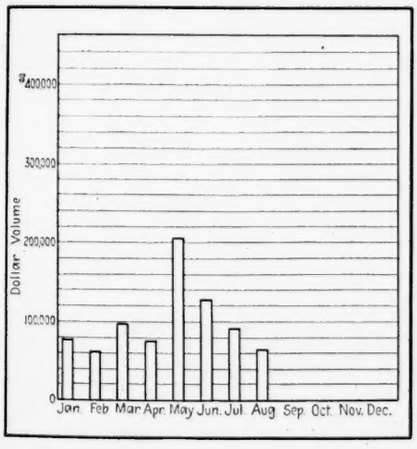
Unit Heaters (Industrial)
Orders in Dollars
August, 1931, $267,361; July, 1931, $297,836; decrease, 10.2%; (Data not reported prior to January, 1931).



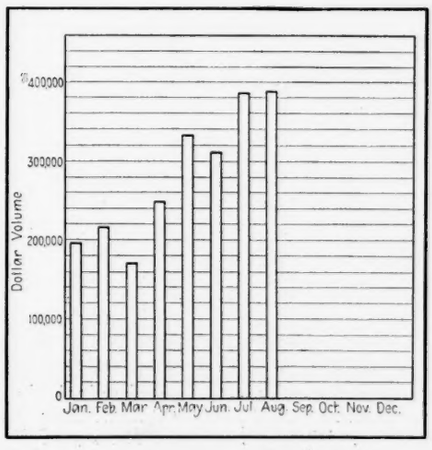
Fans and Blowers
Orders in Dollars
August, 1931, $553,544; July, 1931, $831,520; decrease, 33.4%. (Data not reported prior to January, 1931).



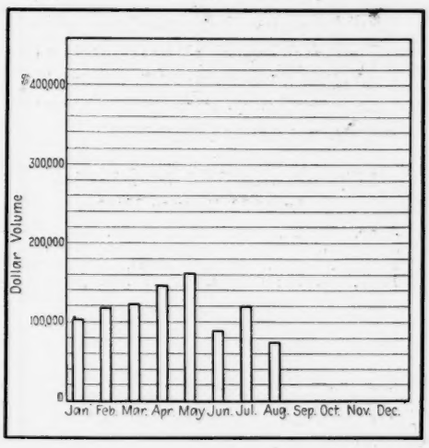
Mechanical Heating Stokers
In number of units installed
August, 1931, 977; July, 1931, 651; increase, 50%; (Data not reported prior to January, 1931).



Air Washers and Air Conditioning Units
Orders in Dollars
August, 1931, $74,615; July, 1931, $93,096; decrease, 19.7%; (Data not reported prior to January, 1931).



Unit Heaters (Schoolroom Type)
Orders in Dollars
August, 1931, $388,317; July, 1931, $386,276; increase, 0.5%; (Data not reported prior to January, 1931).

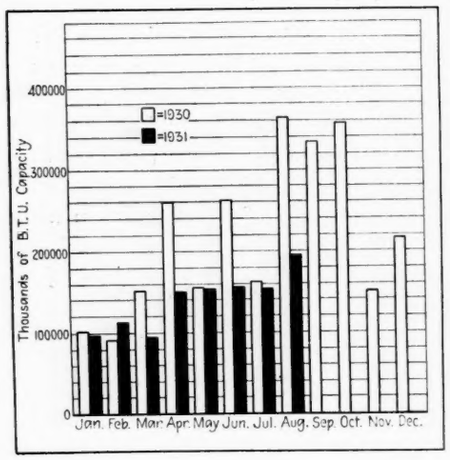


Indirect Heating Surface
Orders in Dollars
August, 1931, $75,507; July, 1931, $110,297; decrease, 31.6%; (Data not reported prior to January, 1931).

(Continued on page 86)

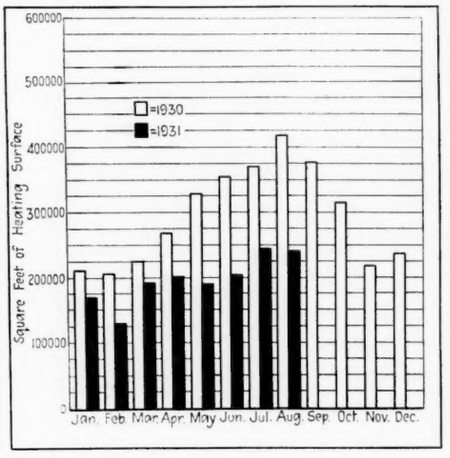
Statistical Service

(Continued from page 85)



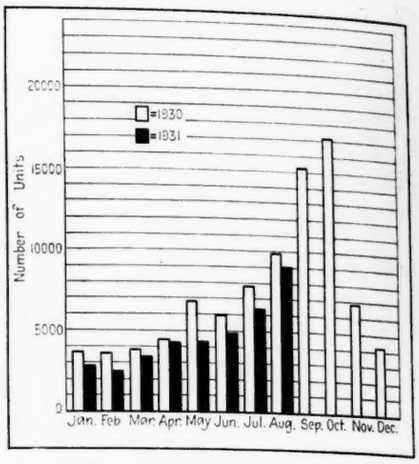
Shipments of Gas-Fired Boilers
In Thousands of B.t.u. Capacity

August, 1931, 195,946; August, 1930, 364,861; decrease over last year, 46.3%; total, eight months, 1931, 1,122,170; total, eight months, 1930, 1,543,109; decrease over last year, 27.2%.



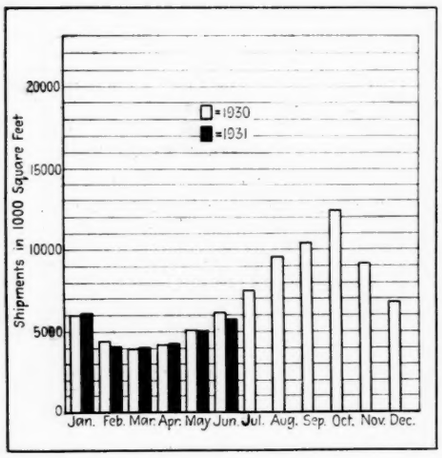
New Orders for Steel Heating Boilers
In Square Feet of Heating Surface

August, 1931, 242,923; August, 1930, 418,685; decrease over last year, 42%; total, eight months, 1931, 1,573,475; total, eight months, 1930, 2,398,947; decrease over last year, 34.3%.



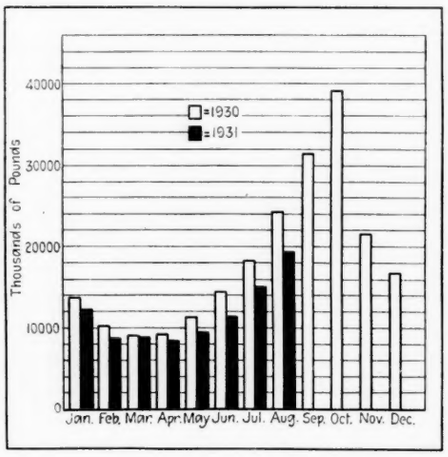
Shipments of Oil Burners
In Number of Units

August, 1931, 9029; August, 1930, 9893; decrease over last year 8.7%; total, eight months, 1931, 37,629; total, eight months, 1930, 45,585; decrease over last year, 17.5%.



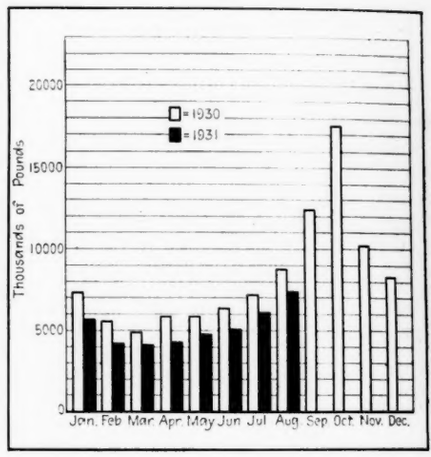
Shipments of Cast Iron Radiators
In 1000 Square Feet

June, 1931, 5759; June, 1930, 6154; decrease over last year, 6.4%; total, six months, 1931, 29,259; total, six months, 1930, 29,852; decrease over last year, 2%.



Shipments of Cast Iron Square Boilers
In Thousands of Pounds

August, 1931, 19,413; August, 1930, 24,178; decrease over last year, 19.7%; total, eight months, 1931, 93,569; total, eight months, 1930, 110,394; decrease over last year, 15.2%.



Shipments of Cast Iron Round Boilers
In Thousands of Pounds

August, 1931, 7309; August, 1930, 8736; decrease over last year, 16.3%; total, eight months, 1931, 41,432; total, eight months, 1930, 51,850; decrease over last year, 20.1%.

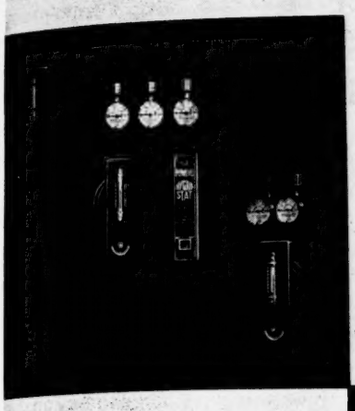
The American Gas Association, in its annual statistical bulletin on the manufactured gas industry, reports an increase in the amount of manufactured gas used for house-heating from 156,100,000 m.c.f. in 1929 to 163,100,000 m.c.f. in 1930, an increase of 27.7%.

Oil burner industry reports from the American Oil Burner Association indicate that there were 96,500 mechanical draft and 23,000 natural draft domestic burners sold during 1930. It is estimated that a total of 654,500 domestic burners were in operation the first of this year, with an estimated number in operation of 774,500 for January 1, 1932.

Commercial oil burners in operation January 1, 1931 are estimated at 42,400.

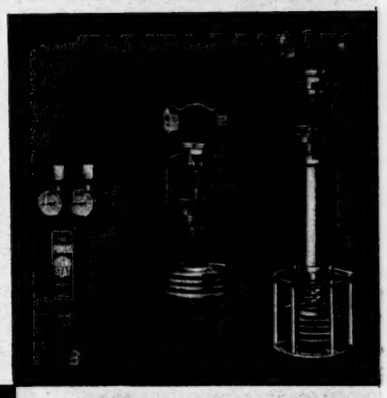
Accurate Dependable Control

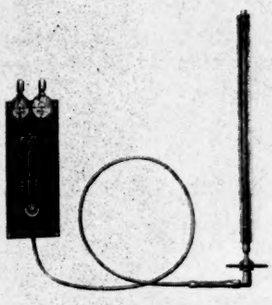
for AIR CONDITIONING

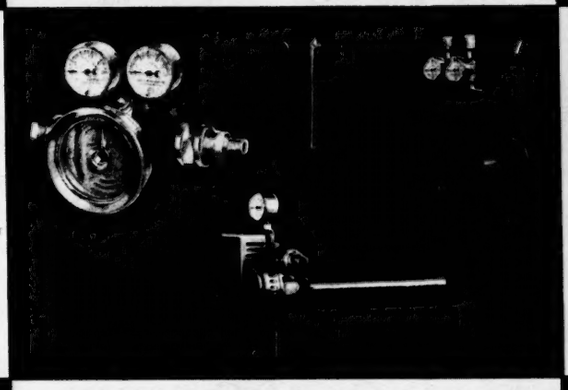


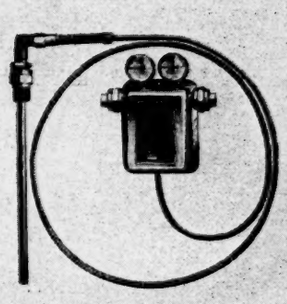
Shown here are some of the many types of Powers instruments used by leading air conditioning firms for temperature, humidity and brine control.

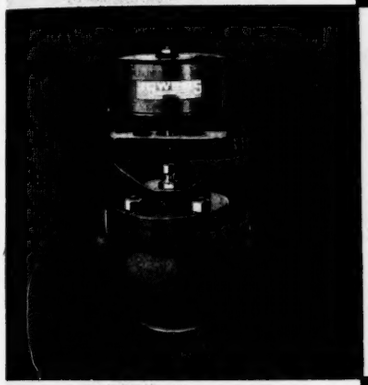
Upon request we shall be glad to mail a copy of our Bulletin No. 251 which shows and describes these and other Powers devices used to control Air Conditioning equipment.

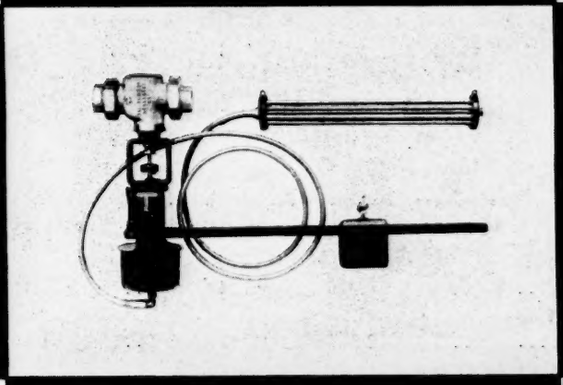


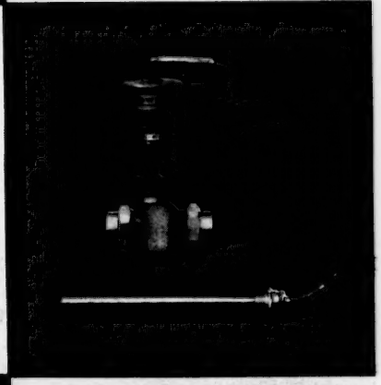












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POWERS

Degree Days and Unit Fuel Consumption in Typical Cities

September, 1931

UNIT fuel consumption figures given below must be corrected for efficiency, heat content of fuel other than that listed below, for radiation emitting other than 240 B.t.u. per hr., and for radiation calculated on a vasis of other than zero outside to 70° inside.

Coal is assumed as having a heat content of 12,000 B.t.u. per lb., gas, 1000 B.t.u. per cu. ft. and oil 140,000 B.t.u. per gal. To correct for other heating values, multiply the fuel consumption listed under the charts by the standard heat content just listed, and divide by the heat content of the fuel actually being used in the installation being calculated.

For radiation installed for any other outside temperature than zero, multiply the fuel consumption given under the charts by 70°, divided by the quantity (70 minus the outside temperature used).

To correct for efficiency, divide the fuel consumption by the efficiency of the heating installation.

For water radiation, multiply the fuel consumption which is given for steam radiation by 5/8.

	New York	Seattle	San Francisco	Chicago	Denver	Boston	St. Louis	Pittsburgh	Minneapolis
Degree Days	22	165	99	42	56	71	16	49	61
Lb. of Coal per Sq. Ft. of Radiation this month	0.176	1.320	0.792	0.336	0.448	0.568	0.128	0.392	0.488
Gal. of Oil per Sq. Ft. of Radiation this month	0.015	0.113	0.068	0.029	0.038	0.049	0.011	0.034	0.042
Cu. Ft. of Gas per Sq. Ft. of Radiation this month	2.11	15.84	9.50	4.03	5.38	6.82	1.54	4.70	5.86

(See Footnote)

	Los Angeles	Baltimore	Philadelphia	New Orleans	Atlanta	Cleveland	Cincinnati	Detroit
Degree Days	0	10	13	0	13	47	40	48
Lb. of Coal per Sq. Ft. of Radiation this month	..	0.080	0.104	..	0.104	0.376	0.320	0.384
Gal. of Oil per Sq. Ft. of Radiation this month	..	0.007	0.009	..	0.009	0.032	0.027	0.033
Cu. Ft. of Gas per Sq. Ft. of Radiation this month	..	0.96	1.25	..	1.25	4.51	3.84	4.61

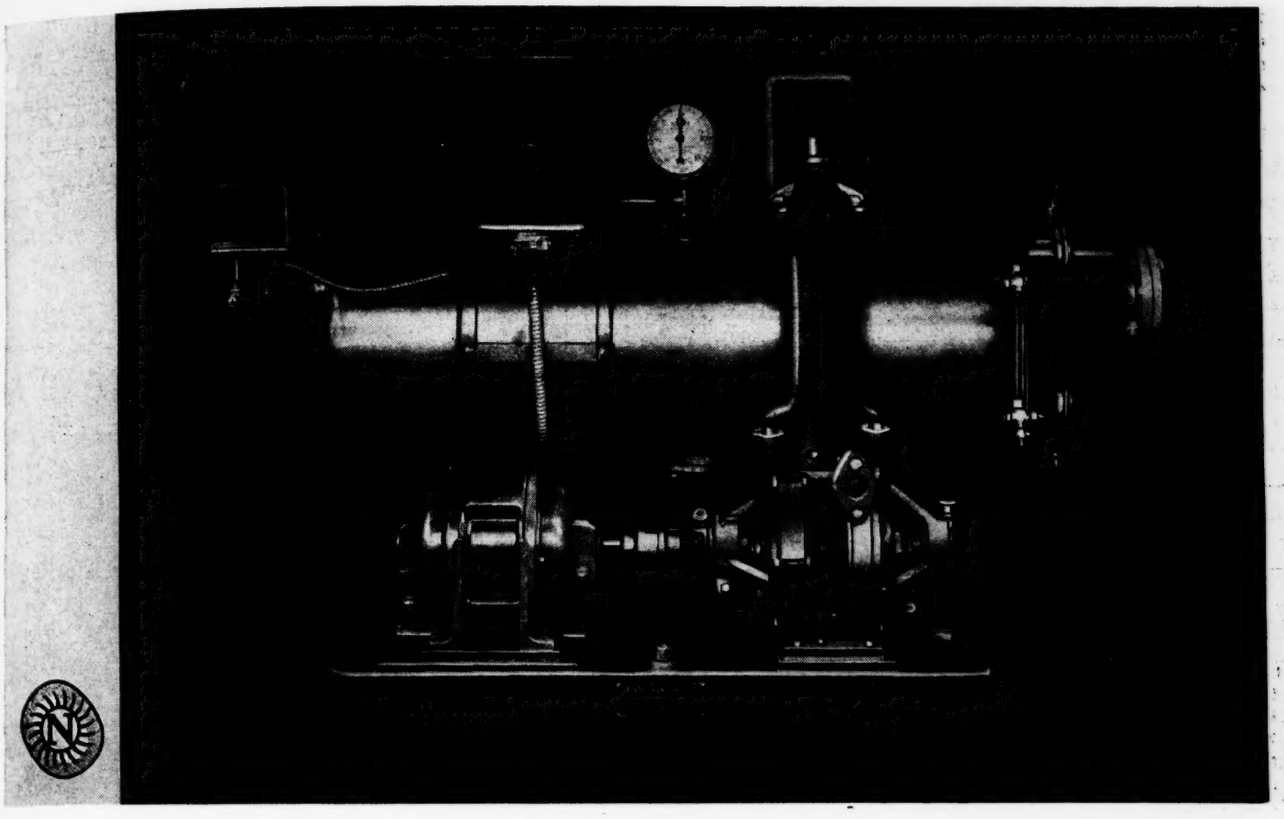
(See Footnote)

	Buffalo	Birmingham	Indianapolis	Memphis	Des Moines	Kansas City	Louisville	Galveston
Degree Days	61	2	32	4	49	13	22	0
Lb. of Coal per Sq. Ft. of Radiation this month	0.488	0.016	0.256	0.032	0.392	0.104	0.176	..
Gal. of Oil per Sq. Ft. of Radiation this month	0.042	0.001	0.022	0.003	0.034	0.009	0.015	..
Cu. Ft. of Gas per Sq. Ft. of Radiation this month	5.86	0.19	3.07	0.38	4.70	1.25	2.11	..

(See Footnote)

Fuel consumption figures must be corrected for local conditions as explained above.

MORE WORK *FROM* LESS POWER
with a Jennings Vacuum Heating Pump



Jennings Vacuum Heating Pumps are furnished in single or duplex types with capacities of 4 to 400 g.p.m. of water and 3 to 171 cu. ft. per min. of air. For serving up to 300,000 sq. ft. equivalent direct radiation. Write for Bulletin 85.

A unique principle of operation, which provides greater capacity at less horsepower, gives the Jennings Vacuum Heating Pump the ability to handle peak loads of air and condensation efficiently and economically.

Air and water are pumped separately. Air capacity is not affected by the volume of water being pumped. Water capacity remains constant even when air is being handled. The combined air and water capacity of the pump is maximum air capacity plus maximum water capacity.

Generous capacity clears the heating system rapidly so that the pump need only operate for short periods at a time. Less horsepower is required to drive a Jennings Pump since neither the air nor the water unit is ever overloaded by having to handle air and water together.

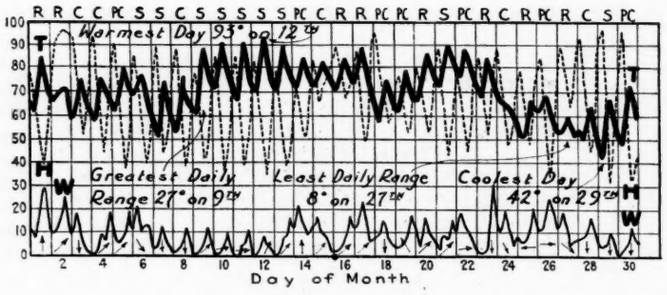
NASH ENGINEERING CO.
81 Wilson Rd., So. Norwalk, Conn.

VACUUM PUMPS AND COMPRESSORS FOR AIR AND GAS • RETURN LINE AND AIR LINE VACUUM STEAM HEATING PUMPS • CONDENSATION PUMPS • FLAT BOX PUMPS • CENTRIFUGAL PUMPS • SUCTION (SELF-PRIMING) CENTRIFUGAL PUMPS • SUMP PUMPS • SEWAGE PUMPS • PNEUMATIC SEWAGE EJECTORS

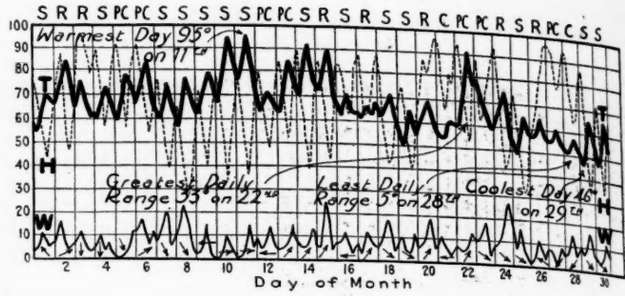
Jennings Pumps

The Weather

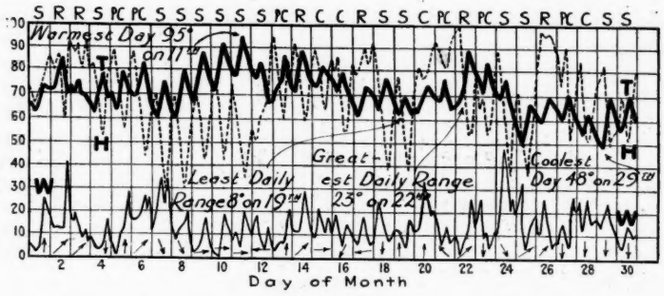
September, 1931



Pittsburgh

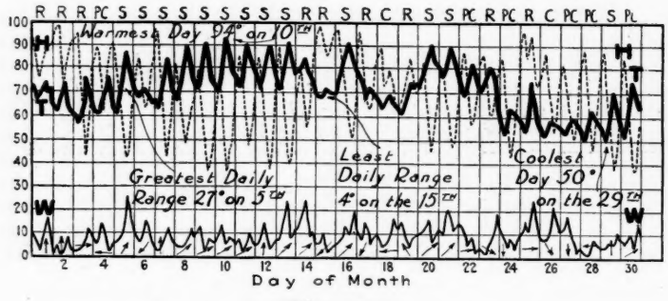


Boston

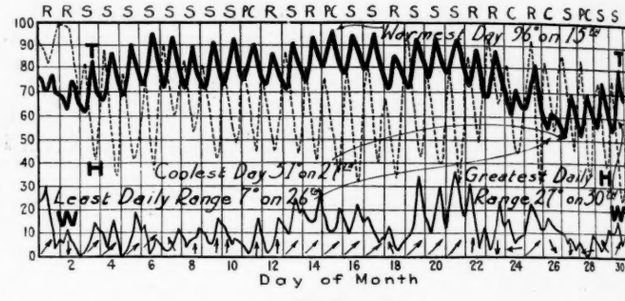


New York

(Hourly Observation of the Relative Humidity Plotted on this Chart



Chicago

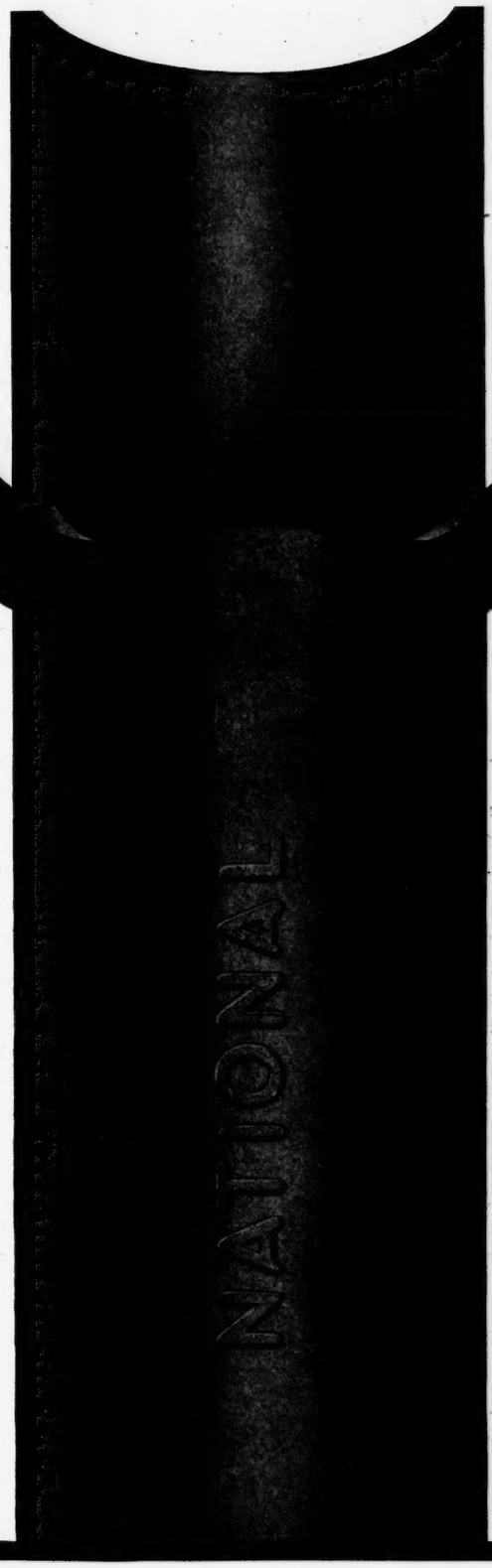


St. Louis

	New York	Boston	Pittsburgh	Chicago	St. Louis
Highest temperature, deg. F.	95	95	93	94	96
Date of highest temperature	11	11	12	10	15
Lowest temperature, deg. F.	48	46	42	50	51
Date of lowest temperature	29	29	29	29	27
Greatest daily range, deg. F.	23	33	27	27	27
Date of greatest daily range	22	22	9	5	30
Least daily range, deg. F.	8	5	8	4	7
Date of least daily range	19	28	27	15	26
Mean temperature for month, deg. F.	71.2	66.9	70.3	71.2	76.9
Normal mean temperature for month, deg. F.	66.8	63.3	66.4	65.2	70.5
Total precipitation, this month, inches	1.15	1.67	3.81	5.14	5.66
Total snowfall, this month, inches	0	0	0	0	0
Normal precipitation, this month, inches	3.39	3.14	2.58	3.14	3.46
Total wind movement, this month, miles	9,159	5,145	5,768	6,107	7,470
Average hourly wind velocity, miles	12.7	7.1	8.0	8.5	10.4
Prevailing direction of wind	N.	N.W.	S.W.	S.W.	S.W.
Number of clear days	14	16	11	12	20
Number of partly cloudy days	9	7	9	10	7
Number of cloudy days	7	7	10	8	3
Number of days with precipitation	6	8	11	13	8
Number of days with snowfall	None	None	None	None	None
Snow on ground, at end of month	None	None	None	None	None

Plotted from records especially compiled for HEATING AND VENTILATING by the United States Weather Bureau.
Heavy lines indicate temperatures in degrees F. Light lines indicate wind in miles per hour.
Broken lines indicate humidity in percentage from readings at 8 a. m., 12 m., and 8 p. m.
S—clear, PC—partly cloudy, C—cloudy, R—rain, Sn—snow. Arrows fly with prevailing directions of w

SMOOTH WALLS FORETELL SMOOTHER SERVICE



From the very start, smoother service and longer life may be expected from pipe whose walls are so remarkably smooth and clean! A glance tells you that galvanizing or other protective coatings will adhere uniformly and effectively. For the rough, corrosive mill-scale (principal cause of "pitting") has been removed by a special rolling or breakdown process at the mill. Naturally, this leaves nothing to obstruct full flow, nor to damage valve seats or clog small orifices.

The Scale Free Process—applied to butt-weld sizes ½ to 3-inch—is an exclusive "NATIONAL" feature. Used in addition to Spellerizing, this extra rolling gives still another "plus" value to NATIONAL

America's Standard Wrought Pipe

NATIONAL TUBE COMPANY
Subsidiary of United States Steel Corporation
PITTSBURGH, PA.

SCALE FREE PIPE
SPELLERIZED